Appendix I
Section 1: USGS - Portland District Fixed Monitoring Stations
Section 2: Walla Walla District TDG Report

U.S. Department of the Interior
U.S. Geological Survey

Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

Water-Resources Investigations Report 01–4005

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS

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Cover Photograph. Columbia River at John Day Dam, April 2000. (*Photograph by Amy Brooks, U.S. Geological Survey)*

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By DWIGHT Q. TANNER AND MATTHEW W. JOHNSTON

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Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

By Dwight Q. Tanner and Matthew W. Johnston

ABSTRACT

Excessive total dissolved gas pressure can cause gas-bubble trauma in fish downstream from dams on the Columbia River. In cooperation with the U.S. Army Corps of Engineers, the U.S. Geological Survey collected data on total dissolved gas pressure, barometric pressure, water temperature, and probe depth at eight stations on the lower Columbia River from the John Day forebay (river mile 215.6) to Camas (river mile 121.7) in water year 2000 (October 1, 1999, to September 30, 2000). These data are in the databases of the U.S. Geological Survey and the U.S. Army Corps of Engineers. Methods of data collection, review, and processing, and quality-assurance data are presented in this report.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) operates several dams in the Columbia River Basin, which encompasses 259,000 square miles of the Pacific Northwest. These dams are multipurpose facilities that fill regional needs for flood control, navigation, irrigation, recreation, hydropower production, fish and wildlife habitat, water-quality maintenance, and municipal and industrial water supply. When water is released over the spillways of these dams, air is entrained in the water, sometimes increasing the concentration of total dissolved gas (TDG) downstream from the spillways in excess of the U.S. Environmental Protection Agency's water-quality criterion of 110-percent saturation for the protection of freshwater aquatic life. Concentrations above this criterion have been shown to cause gas-bubble trauma in fish and adversely affect other aquatic organisms (U.S. Environmental Protection Agency, 1986). USACE minimizes spill and regulated streamflow in the region to minimize the production of excess TDG downstream from its dams. USACE collects real-time TDG data (data available within about 4 hours of current time) upstream and downstream from the dams in a network of fixed-station monitors.

Background

Real-time TDG data are vital to USACE for dam operation and for monitoring compliance with environmental regulations. The data are used by water managers to maintain water-quality conditions that facilitate fish passage and survival in the lower Columbia River. The U.S. Geological Survey (USGS), in cooperation with the Portland District of USACE, has collected TDG and related data in the lower Columbia River every year beginning in 1996. A report was published in 1996 that contained a description of the methods of data collection, the quality-assurance program, and summaries of data (Tanner and others, 1996).

Data-collection methods and quality-assurance plans have changed significantly since 1996. In water year 2000, new TDG/temperature probes and new methods of calibration in the laboratory and in the field were used.

To provide a suitable data set for water managers to model TDG in the lower Columbia River, the real-time hourly data for water year 2000 were corrected or deleted to reflect measurements made during instrument calibration. The reviewed and corrected hourly data are stored in a USGS data base (Automated Data Processing System—ADAPS) and in a USACE data base at http://www.nwd-wc.usace.army.mil/TMT/tdg_data.

Purpose and Scope

The purpose of TDG monitoring is to provide USACE with (1) real-time data for managing streamflows and TDG levels upstream and downstream from its project dams in the lower Columbia River and (2) reviewed and corrected TDG data to evaluate conditions in relation to water-quality criteria and to develop a TDG data base for modeling the effect of various management scenarios of streamflow and spill on TDG levels.

This report describes the data-collection techniques and quality-assurance data for the TDG monitoring program on the Columbia River from the forebay of the John Day dam (river mile [RM] 215.6) to Camas (RM 121.7). Data for water year 2000 included total dissolved gas pressure, barometric pressure, and water-temperature at eight fixed stations on the lower Columbia River (fig. 1, table 1).

Acknowledgments

We wish to acknowledge the aid and funding support of the U.S. Army Corps of Engineers. Our special thanks to James L. Britton (USACE) for technical and logistical support of the project. The authors also acknowledge Amy Brooks and Tirian Mink (USGS) for assistance in data collection and for preparing summaries of data. Howard E. Harrison, formerly of the USGS, helped develop several of the data-collection and quality-assurance protocols.

METHODS OF DATA COLLECTION

Instrumentation

Instrumentation at each fixed station consisted of a TDG probe, an electronic barometer, a data-collection platform (DCP), and a power supply. The TDG probe was manufactured by Hydrolab Corporation. The probe had individual sensors for TDG, temperature, and probe depth (unvented sensor). The TDG sensor consisted of a cylindrical framework wound with a length of Silastic

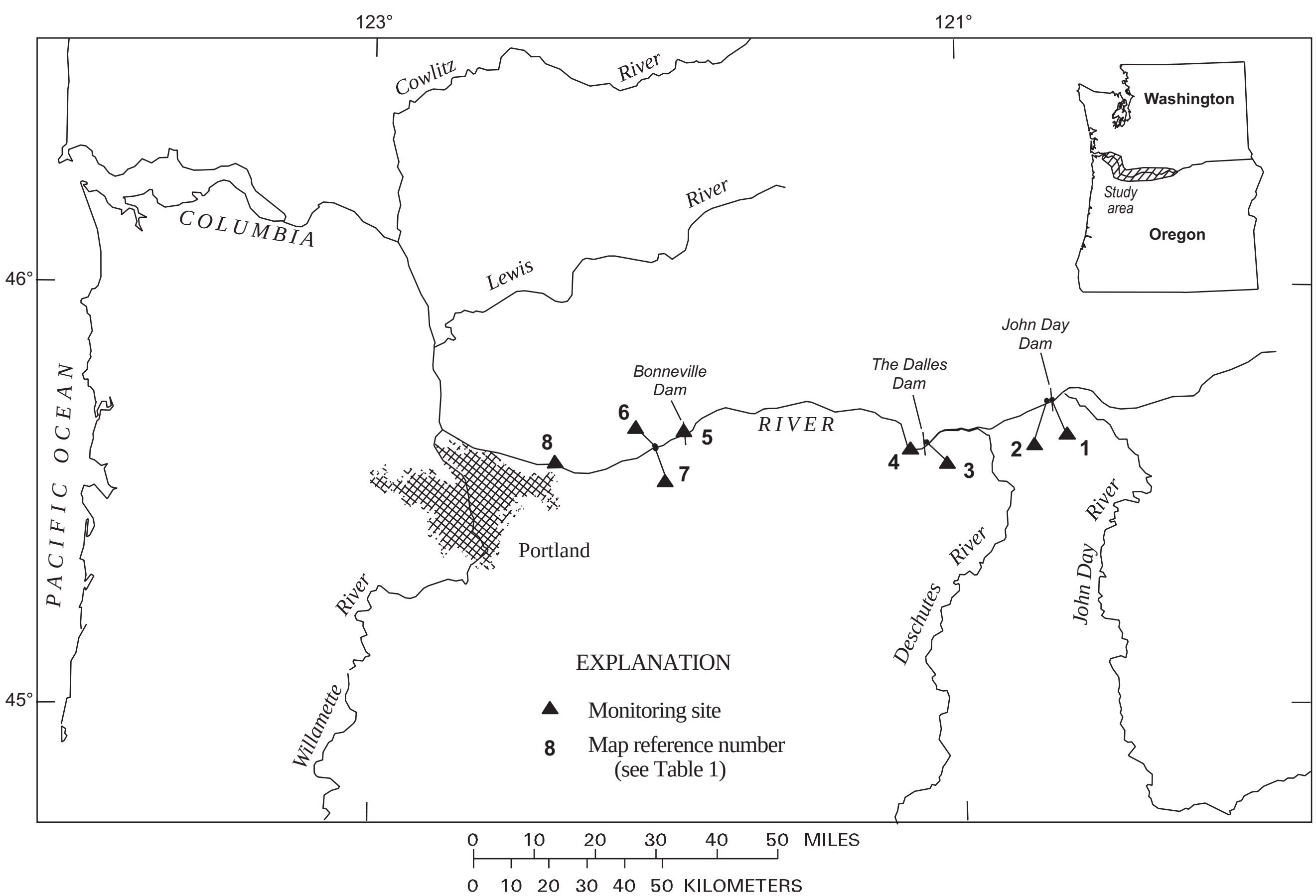

Figure 1. Total dissolved gas fixed stations, lower Columbia River, Oregon and Washington, water year 2000.

Table 1. Total dissolved gas fixed stations, lower Columbia River, Oregon and Washington, water year 2000

[Map reference number refers to figure 1; USACE, U.S. Army Corps of Engineers; Columbia River mile locations were determined from U.S. Geological Survey (USGS) 7.5-minute topographic maps; stations are referenced by their abbreviated name in this report]

Map reference number	USACE site identifier	Columbia River mile	USGS station number	USGS station name (abbreviated station name)	Latitude	Longitude	Period of record
1	JDA	215.6	454257120413000	Columbia River at John Day Dam forebay, Washington (John Day forebay)	45˚ 42’ 57”	120˚ 41’ 30”	March 24 – September 19
2	JHAW	214.7	454249120423500	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)	45˚ 42’ 49”	120˚ 42’ 35”	March 23 – September 19
3	TDA	192.6	453712121071200	Columbia River at The Dalles Dam forebay, Washington (The Dalles forebay)	45˚ 37’ 12”	121˚ 07’ 12”	March 24 – September 20
4	TDDO	188.9	14105700	Columbia River at The Dalles, Oregon (The Dalles downstream)	45˚ 36’ 27”	121˚ 10’ 20”	March 23 – September 19
5	BON	146.1	453845121562000	Columbia River at Bonneville Dam forebay, Washington (Bonneville forebay)	45˚ 38’ 45”	121˚ 56’ 20”	Year-round
6	SKAW	140.5	453651122022200	Columbia River, right bank, near Skamania, Washington (Skamania)	45˚ 36’ 51”	122˚ 02’ 22”	February 23 – September 18
7	WRNO	140.4	453630122021400	Columbia River, left bank, near Dodson, Oregon (Warrendale)	45˚ 36’ 30”	122˚ 02’ 14”	Year-round
8	CWMW	121.7	453439122223900	Columbia River, right bank, at Washougal, Washington (Camas)	45˚ 34’ 39”	122˚ 22’ 39”	February 24 – September 18

(dimethyl silicon) tubing. The tubing was tied off at one end and the other end was connected to a pressure transducer. After the TDG pressure in the river equilibrated with the gas pressure inside the tubing (about 15 to 20 minutes), the pressure transducer produced a measure of the TDG pressure in the river. The water-temperature sensor was a thermocouple. The barometer was contained in the display unit of the Model TBO-L, a total dissolved gas meter manufactured by Common Sensing, Inc.

The TDG probe was connected by a heavy-duty, weatherproof cable to a Sutron Model 8200 DCP. The DCP had three basic functions: sensor interfacing, data storage, and data transmission to the Geostationary Operational Environmental Satellite (GOES) system (Jones and others, 1991). A crossed Yagi antenna was connected to the DCP using a coaxial cable. The antenna was mounted on a mast to provide transmission to the GOES system.

The barometer, TDG probe, and the DCP were powered by a 12-volt gelled-electrolyte battery. The battery was charged by a regulated-voltage circuit from a solar panel and/or a 120-volt alternating-current line.

The DCP was programmed to record and transmit five parameters: barometric pressure (in millimeters of mercury), TDG pressure (in millimeters of mercury), probe depth (in feet), water temperature (in degrees Celsius), and battery voltage (in volts). Battery-voltage data were monitored to determine whether the instrumentation was receiving adequate power. The data for each parameter were logged electronically every hour, on the hour, and stored in the DCP memory. Every 4 hours, the DCP transmitted the most recent 12 hours of logged data to the GOES satellite. Consequently, each piece of data was transmitted three times to protect against data loss. The GOES satellite retransmitted the data to a direct readout ground station, where the data were automatically decoded and transferred to the USACE data base (Columbia River Operation Hydromet Management System—CHROMS), and to the USGS ADAPS data base. During the fixed-station calibration visits, the DCP-stored data were downloaded to a palmtop computer. When it was necessary to fill in any real-time data lost during satellite transmission, these data were supplied to USACE and also loaded into the database at the USGS office in Portland, Oregon.

At one site, John Day tailwater, two TDG probes were installed inside the same probe housing, which was perforated at the end and extended into the flow of the Columbia River. The primary probe was at the distal end of the plastic pipe and the secondary probe was located about 1 foot (measured vertically) above the first. This was done for the following reasons: (1) to ensure that data were reliably collected at this important site and (2) to provide an assessment of the variability of the TDG measurement.

Calibration of Instruments in the Laboratory

The fixed station monitors were calibrated every 2 weeks from March 10 to September 15, 2000, and every 3 weeks for the remainder of the year, at which time Warrendale and Bonneville forebay were the only sites in operation. The general procedure was to check the operation of the TDG probe in the field without disturbing it, replace the field probe with one that had just been calibrated in the laboratory, and then check the operation of the newly deployed field probe. The details of the laboratory calibration procedure follow.

Each time a TDG probe was removed from its 2- or 3-week deployment in the river, it was calibrated in the Oregon District laboratory before being redeployed. First, the TDG value in millimeters of mercury was measured in ambient conditions with the TDG membrane still attached to the sensor and compared to the ambient barometric pressure as measured by a handheld aneroid barometer (fig. 2, item 1). (The aneroid barometer was calibrated every 2 weeks at the National Weather Service facility in Portland, Oregon.) If the measurement by the TDG probe and the measurement by the aneroid barometer were approximately equal, this check was considered acceptable.

Pressure calibrations were done using a Netech DigiMano 2000 digital pressure gage, which was certified according to standards of the National Institute of Standards and Technology (NIST). The end of the TDG probe containing the sensors was put in a plastic pressure chamber and the pressure was increased 200 mm Hg (millimeters of mercury) above the ambient barometric pressure (fig. 2, item 2). The pressure measured by the TDG sensor should increase gradually, until it reaches a level approximately 200 mm Hg above barometric pressure, within about 10 minutes. This would indicate that the pressurized air was penetrating the membrane at a gradual rate. On occasions when there was an opening torn in the membrane, the pressure measured by the TDG sensor would increase rapidly, indicating that the membrane should be replaced.

HYDROLAB LABORATORY PROCEDURES

To be done when a Hydrolab is brought in from a 2 or 3-week deployment.

Hyrolab # 37603 Lab barometer ID dqt
TDG sensor # 63369 Date baro last calib. 5/18/00
Site Hyd. was deployed SKAW Today's date 6/13/00
Date removed 6/5/00 Checked by TM

1. TEST LOW CALIBRATION WITH MEMBRANE ATTACHED.

Lab BP 765 mm Hydrolab Pt 762 mm Time 1403

2. TEST HYDROLAB WITH DIGITAL PRESSURE GAGE AND PRESSURE CHAMBER.

Lab BP + 200mm = 965 mm

Before applying 200 mm pressure Hydrolab Pt 762 mm Time 1403
After applying pressure Hydrolab Pt 964 mm Time 1412

3. TEST HYDROLAB WITH CLUB SODA.

Before soda test Hydrolab Pt 760 mm Time 1519
High pressure, soda test Hydrolab Pt 1011 mm Time 1520
Low pressure, after soda test Hydrolab Pt 728 mm Time 1522

(If the Hyd. does not perform well on #1 - #3 above, re-evaluate the corresponding site record.)

Remove TDG membrane, clean the membrane, air dry, store in dessicator.
Allow TDG sensor to air dry for at least 24 hours.
Then test Hydrolab before redeployment, below.

---

1. CALIBRATE TDG WITH DIGITAL PRESSURE GAGUE.

Date 6/14/00
Time 1415

Lab BP 762 mm
Hydrolab Pt 760 mm

862 860
Baro+100mm expected/meas.

962 961
Baro+200mm expected/meas.

1062 1061
Baro+300mm expected/meas.

If any readings are >2 mm off, do a 2-point calibration at barometric pressure and barometric pressure + 200 mm and note below.

2. INSTALL DRY MEMBRANE AND INSTALL THE SENSOR GUARD.

3. TEST HYDROLAB WITH CLUB SODA. 6/15/00 baro=767

Before soda test Hydrolab Pt 771 mm Time 0907
High pressure, soda test Hydrolab Pt 1002 mm Time 0908
Low pressure, after soda test Hydrolab Pt 746 mm Time 0909

4. CLEAN AND DRY THE HYDROLAB.

5. CHECK MEMBRANE FOR INTERNAL MOISTURE AFTER THE OUTSIDE OF THE MEMB. HAS HAD TIME TO DRY

Label as ready for field deployment, with date. Completed Date 6/16/00 Time 1400

Figure 2. Laboratory calibration form.

Subsequently, the TDG membrane / TDG sensor units were tested for responsiveness to supersaturation by inserting the probe into a container filled with supersaturated carbonated water (club soda). If the membrane/sensor was operating correctly, the measured TDG rose to at least 1,000 mm Hg in 2 to 3 minutes (fig. 2, item 3). If the response was not this large, the membrane was replaced.

Next, the TDG membrane was cleaned with a squirt bottle of tap water, then removed from the sensor. The TDG membrane was dried in a desiccator for at least 24 hours, and, at the same time, the TDG sensor was air dried at room temperature. This step was important because water sometimes collected inside the tubular membrane due to condensation. If the condensation is not removed, it can slow the equilibration of air pressure between the outside of the membrane and the TDG sensor.

After the TDG membrane and sensor had been dried, the TDG sensor, with the membrane still unattached, was tested at ambient pressure conditions (i.e. barometric pressure, as measured by the aneroid barometer) and at added pressures of 100 mm Hg, 200 mm Hg, and 300 mm Hg measured by the pressure gage, which was the primary standard (lower half of fig. 2, item 1). For example, using the barometric pressure of 760 mm Hg, the added pressures of 0, 100, 200, and 300 mm Hg correspond to TDG percent saturations of 100%, 113.2%, 126.3%, and 139.5%, respectively. The results of these calibrations for water year 2000 are shown in figure 3. Almost all of the calibrations were within 1-percent saturation of total dissolved gas. One outlier, for 0 mm Hg added pressure at Skamania, was 5.3 percent larger than expected. This result indicated that the sensor was defective, and it was replaced.

If any of the measurements differed more than 3 mm Hg from the primary standard, the sensor was calibrated at two points, barometric pressure and barometric pressure plus 200 mm Hg. Then the calibration of the TDG sensor was checked a second time according to the procedure above to be sure that it was correctly calibrated at the various pressures.

After the pressure check and calibration (if needed) of the TDG sensor, the dried membrane was reattached to the sensor, and the sensor guard was screwed back on the probe. Then another test was done for responsiveness to supersaturation with "club soda" (carbonated water) (lower half of fig. 2, item 3). Again, if the membrane/sensor was operating correctly, the measured TDG rose to at least 1,000 mm Hg in 2 or 3 minutes. If the response was not this large, the membrane was replaced. This second test, with club soda, was done because the process of installing the sensor guard had been found to abrade the TDG membrane, so the test ensured that the membrane was still functional.

The final step was to inspect the inside of the membrane for moisture (lower half of fig. 2, item 5.) If no moisture was visible, the TDG probe was labelled as ready for field deployment.

In addition to the TDG probes that were calibrated for replacement in the field each 2 to 3 week calibration interval, one TDG probe was calibrated every 2 to 3 weeks for use in the field as a secondary standard. This was the probe designated "Lab" on figure 3. The TDG sensor was calibrated in the manner described above, and, additionally, the temperature calibration was checked in a water bath at a temperature near to the ambient river temperature at the time. The temperature displayed for the probe thermistor was compared to the temperature as read to the nearest 0.1 degrees Celsius with a NIST-traceable mercury thermometer. The TDG temperature probe for the "Lab" Hydrolab could not be adjusted to display the correct temperature, so the needed adjustment (if any) was recorded for later use during the field calibrations.

Calibration of Instruments in the Field

The fixed station monitors were calibrated every 2 weeks from March 10 to September 15, 2000, and every 3 weeks for the remainder of the year, at which time Warrendale and Bonneville forebay were the only sites in operation. The general procedure was to check the operation of the field probe without disturbing it, then replace the field probe with one that had been recently calibrated in the laboratory (as described above) and check the operation of the newly deployed field probe. The details of the field procedure follow.

The first step was to fill out the heading of the field sheet (fig. 4) indicating site, date and time, weather conditions, and identification of the equipment at the site. Then the "LAB" TDG probe (the secondary standard) was placed in the river at a location adjacent to the field probe (fig. 4, item 1). The instrument shelter (a waterproof metal enclosure) was checked to ensure that the vent was unobstructed so that the barometer could effectively measure the ambient barometric pressure (fig. 4, item 2).

A palmtop computer was connected to the DCP, allowing for data retrieval and program adjustment and

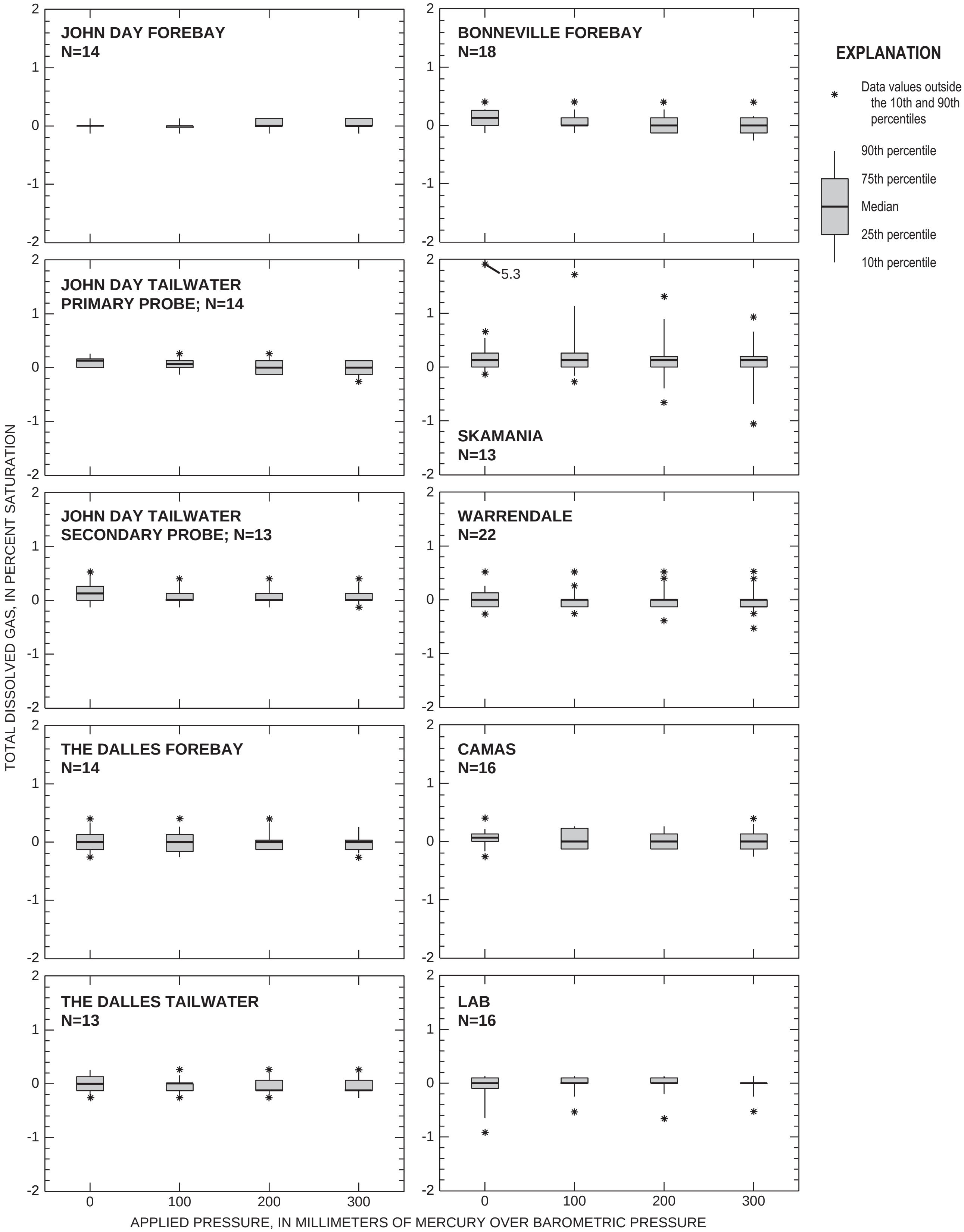

Figure 3. Accuracy of total dissolved gas sensors when compared to a primary standard after field deployment. (Total dissolved gas value from primary standard minus value from field total dissolved gas probe.)

HYDROLAB TDG FIELD INSPECTION/CALIBRATION SHEET (1/00 version)

----- USGS Portland, Oregon (503)251-3200 ---------------------

Site ID: BON Date: 5-24-00 Arrive time: 1020

Personnel: Brooks Purpose: calibration

Weather: sunny Air temperature: 20.8 C

Observed spill conditions: All gates

DCP# 37409 TBO# 19

Lab Hydrolab # 33674 Date last cal. 5-18-00

Lab Barometer ID DQT Date last cal. 5-18-00

1. **WITHOUT MOVING THE OLD FIELD HYDROLAB, PLACE LAB HYDROLAB IN RIVER AT DEPTH OF OLD FIELD HYDROLAB** Time: 1025

2. IS SHELTER VENT OBSTRUCTED (Y/N): N

3. **CONNECT COMPUTER AND CHECK DCP**
   Dump logged data to file: 5/12/2000 .LOG (3 kb)
   Most recent logged data: time 1700 baro 763 temp 14.64 depth 17.46 Pt 836
   DCP clock time: 17:33:30 GMT time (watch): 17:33:29
   Reset clock (Y/N): N
   Recording status (check one): X ON&TX, ___ ON&FT, ___ ON, ___ OFF
   Antenna angle approx. 35-40 degrees to horizon (Y/N): Y
   Antenna direction approx. 180 degrees - south (Y/N): Y
   Battery minimum: 13.26 VDC Battery maximum: 13.34 VDC
   Next transmission 18:11:10 GMT Error messages (Y/N): N (log in notes)
   Clear status (Y/N): Y

4. **CHECK POWER AND CHARGING SYSTEM WITH MULTI-METER**
   AC (at outlet): 120.0 VAC
   DISCONNECT battery IF next transmission NOT imminent
   BATTERY (at poles): 13.33 VDC
   REGULATOR (at leads to battery from DCP = 13.8VDC/.75A): 13.29 VDC
   RECONNECT battery, then disconnect right side DCP bus bar
   SOLAR PANEL OR AC/DC CONVERTOR (at PWR IN screws): 13.76 VDC
   RECONNECT bus bar

5. BAROMETRIC PRESSURE

   763 mm - 760 mm = 3 mm IF |*5*| > 10mm, replace TBO
   Lab BP TBO BP *5*

   763 mm - 764 mm = -1 mm
   Lab BP DCP BP Back Shift

   Reset DCP Old offset 0.001 New offset 0 Time: 1037

6. TEMPERATURE Uncorrected Lab WT = 14.61 C

   14.71 C - 14.67 C = +.04 C Time: 1038
   Corrected Lab WT Old Field Hyd WT Back Shift

NOTES: ____

Page 1

Figure 4. Field inspection/calibration sheet.

7. AFTER A MIN. OF 15 MIN. IF LAB & OLD FIELD HYD PT READINGS HAVE NOT CHANGED 1 MM./2 MIN. AFTER SHAKING **LAB** HYDROLAB OR IF LAB & OLD FIELD HYD ARE CHANGING BUT DIFFERENCE IS CONSTANT:

855 mm - 853 mm = 2 mm   Time: 1054

Lab Hyd PT   Old Field Hyd PT   Back Shift

855-763=92/23

current is shifting lab probe up & down a few feet

Time	Lab Pt	Old Fld Pt
1039	868	836
1045	860	851
1047	857	852
1049	856	853
1050	853	853

8. **CALCULATE MINIMUM SENSOR COMPENSATION DEPTH (MSCD)**
   (Lab PT - Lab BP) / 23 = 4.00 ft.
   Sensor depth at arrival: 17.46 ft.

9. IF OLD FIELD HYD NOT AT OR BELOW MSCD, LOWER OLD FIELD AND LAB HYD TO MSCD. ALLOW TO STABILIZE AND RECORD OLD LAB AND FIELD PT AND WT IN NOTES.

10. **REMOVE OLD FIELD HYDROLAB FROM RIVER**   Record Old Fld. Hydrolab # 33768   Time: 1055

11. **CHECK DEPTH PARAMETER ON OLD FIELD HYDROLAB**
    Depth reading (Hydrolab out of the river) -0.07 ft   Time: 1056

12. **CONNECT NEW FIELD HYDROLAB, CALIBRATE DEPTH PARAMETER, CHECK Pt IN AIR**
    New Field Hydrolab # 37599   Last caibrated 5-18-00
    Depth reading before zeroing -0.13 ft Reset depth to 0.0 ft
    Record Pt reading in ambient air 761 mm   Time: 1057

13. **DEPLOY NEW FIELD HYDROLAB IN RIVER AT 15' OR MAXIMUM DEPTH OF SENSOR HOUSING**
    Sensor depth: 16.32 ft   Time: 1103

14. TEMPERATURE   Uncorrected Lab WT = 14.62 C

    14.72 C - 14.66 C = +.06 C
    Corrected Lab WT   New Field Hyd WT

    Reset DCP   Old offset 0   New offset +.1   Time: 1106

15. AFTER A MIN. OF 15 MIN. IF LAB & NEW FIELD HYD PT READINGS HAVE NOT CHANGED 1 MM./2 MIN. AFTER SHAKING **NEW FIELD** HYDROLAB OR IF LAB & NEW FIELD HYD ARE CHANGING BUT DIFFERENCE IS CONSTANT:

    852 mm - 855 mm = -3 mm   Time: 1124
    Lab Hyd PT   New Field Hyd PT   *15*

Time	Lab Pt	New Fld Pt
1104	853	855
1122	852	856

    IF |*15*| is > 10 mm, replace new Hydrolab with a backup, or do A and B

A. TEST NEW FIELD AND LAB HYD. WITH CLUB SODA:
   New Fld. Hyd. ____________ mm Time: ________
   Lab Hyd. ____________ mm Time: ________

B. TEST NEW FIELD AND LAB HYD. WITH PRESSURE GAGE AND CHAMBER:
   New Fld. Hyd. ambient____________ mm; plus 200mm___________ mm Time: ________
   Lab Hyd. ambient____________ mm; plus 200mm___________ mm Time: ________

IF NEW FLD. HYDROLAB FAILS EITHER TEST, REPLACE IT WITH A BACKUP HYDROLAB.
IF LAB HYDROLAB FAILS EITHER TEST, USE A BACKUP HYDROLAB TEMPORARILY AS THE LAB METER.

16. **CHECK DCP OFFSET FOR Pt = ZERO**   Y/N: Y

17. **SAVE SETUP, CHECK RECORDING STATUS = "ON&TX", DISCONNECT LAPTOP** Y/N: Y

Equipment changed other than Hydrolab (Y/N, item): N, _____________   End time: 1126

NOTES: ____

Page 2

Figure 4. Field inspection/calibration sheet—Continued.

checking (fig. 4, item 3). The data that were logged by the DCP since the last visit were downloaded to the palmtop computer so they could be available in the event that any data were not transmitted by the satellite system. The clock in the DCP was checked and adjusted, if necessary. Antenna alignment and recorded battery voltages were checked and recorded.

The power and charging systems were checked using a digital multimeter (fig. 4, item 4). Some of the sites had 120-volt alternating-current (AC) power service; the voltage of those supplies was checked. With the battery disconnected, its voltage was measured, and the circuit that charges the battery (the regulator) was checked. Finally, the battery was reconnected, and the voltage output of the solar panel or AC/DC converter was checked before its input to the voltage regulator.

The field-deployed electronic barometer was checked and adjusted, if necessary (fig. 4, item 5). The measurement from the secondary standard aneroid barometer ("Lab BP" on figure 4) was compared to the measurement made by the field electronic barometer and displayed by the DCP ("DCP BP" on fig. 4). If there was a difference, the back shift was applied to change the offset value in the DCP program. After this step, the DCP would display the same barometric pressure (to the nearest millimeter of mercury) as the secondary standard, the aneroid barometer. The results of the field calibrations of the electronic barometers at the fixed stations are shown in figure 5. Most of the time, the field barometer was within 1 mm Hg of the secondary standard. At The Dalles forebay site, the spread of data was widest—between plus and minus 2 mm Hg. This probably was the result of a variable signal from the electronic barometer, which resulted in the offset being adjusted one way on one calibration visit and the other way on the next calibration visit.

The performance of the field temperature sensor was documented (fig. 4, item 6). The water temperature measurement made by the secondary standard TDG probe ("Corrected Lab WT") was compared to the measurement made by the nearby field-deployed TDG probe ("Old Field Hyd WT"). The differences were usually less than 0.1ºC (degrees Celsius), indicating the accuracy when compared to the secondary standard (fig. 6).

Performance of the fixed-station TDG sensor was documented (fig. 4, item 7). Values of TDG obtained by the secondary standard TDG sensor ("Lab Hyd PT") were compared to the values obtained by the fixed-station TDG sensor ("Old Field Hyd PT"). For this comparison, it was necessary to wait until the secondary standard reached equilibrium in the river. Usually this equilibration process took about 30 minutes and was considered to be complete when the reading for each probe did not change even 1 mm Hg for a period of 2 minutes. At most sites, there was usually less than a 1 percent TDG difference between the secondary standard and the fixed-station monitor (fig. 7.) At The Dalles site once, and at the Camas site three times, the TDG measurement from the fixed-station monitor was more than 10 percent larger than the measurement from the secondary standard (fig. 7). These were times when

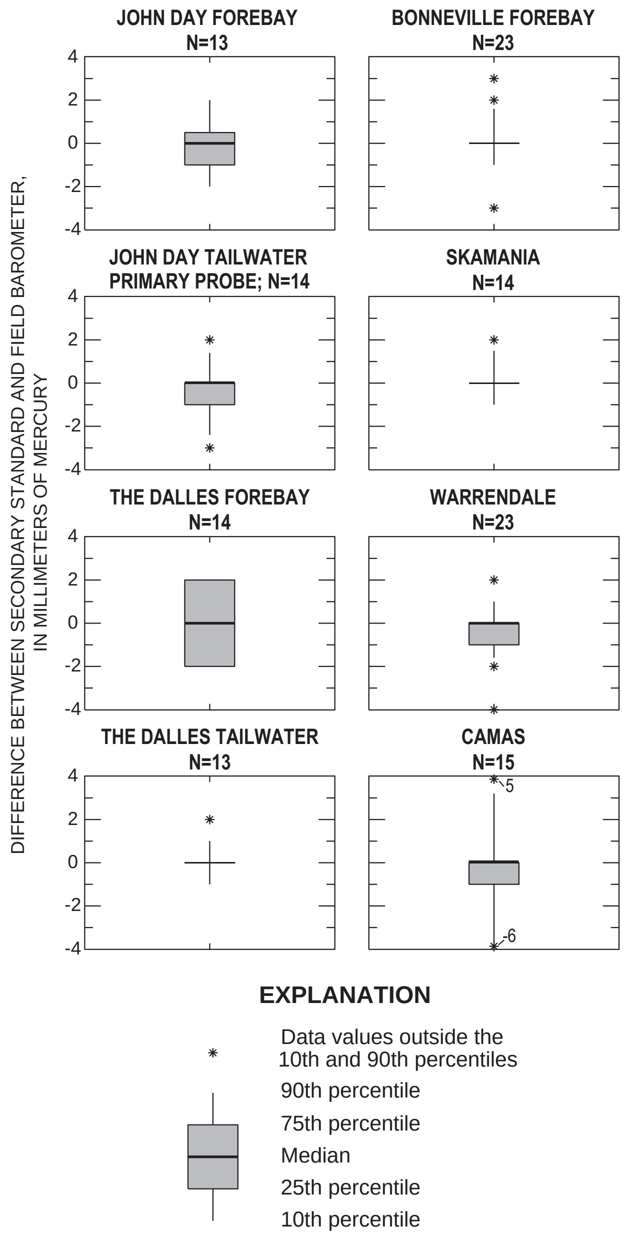

Figure 5. Difference between the secondary standard and the field barometers.

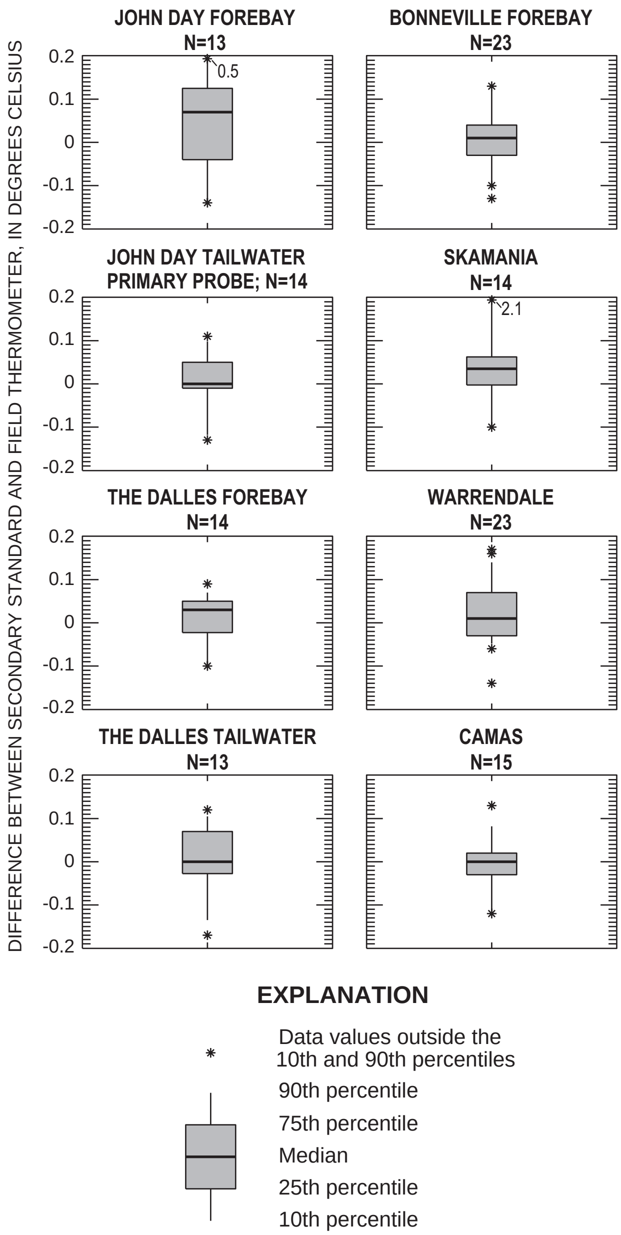

Figure 6. Difference between the secondary standard and the field thermometers.

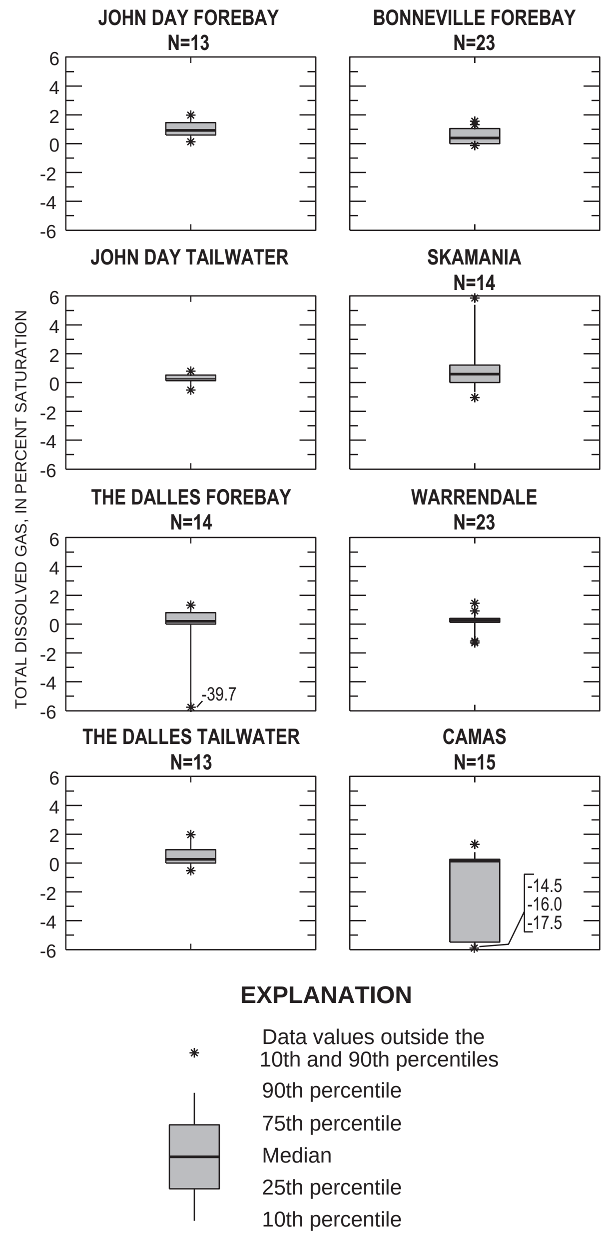

Figure 7. Total dissolved gas difference between the field probe and lab probe initially.

the TDG membrane had been broken, resulting in incorrect TDG measurements.

The minimum compensation depth was calculated and recorded (fig. 4, item 8). This depth, calculated according to a formula derived from Colt (1984, page 104), is the depth above which degassing will occur, due to the decreased hydrostatic pressure. In order to measure TDG accurately, the probe must be deeper than the calculated compensation depth. If the probe was not below minimum compensation depth and it was physically possible to have it that deep, the TDG was measured at the larger depth (fig. 4, item 9).

The probe from the fixed station was removed from the river and the depth parameter was checked when it was above the water surface (fig. 4, items 10 and 11). The depth reading usually differed from zero by about 0.1 or 0.2 feet. These differences were due to the fact that the depth sensor on the TDG probe was not vented to the outside atmosphere, so that changes in barometric pressure affected the measured depth of the TDG probe.

The newly calibrated TDG probe was connected to the fixed-station equipment, the functions of depth and TDG measurement were checked, and the zero point for depth measurement was calibrated (fig. 4, item 12).

The TDG probe was allowed 5 to 10 minutes to equilibrate in the river then the temperature measurement function was checked and calibrated (fig. 4, item 14). Using the electronic offsets in the DCP, the measurement made by the newly calibrated TDG probe was made to read the same temperature as measured by the secondary standard for temperature (the laboratory-calibrated TDG probe).

The final field calibration step (fig. 4, item 15) was to check the TDG measurement in the river made by the newly calibrated fixed-station probe against that made by the secondary standard (the laboratory-calibrated TDG probe). These two values usually were within 2 percent TDG of each other (fig. 8).

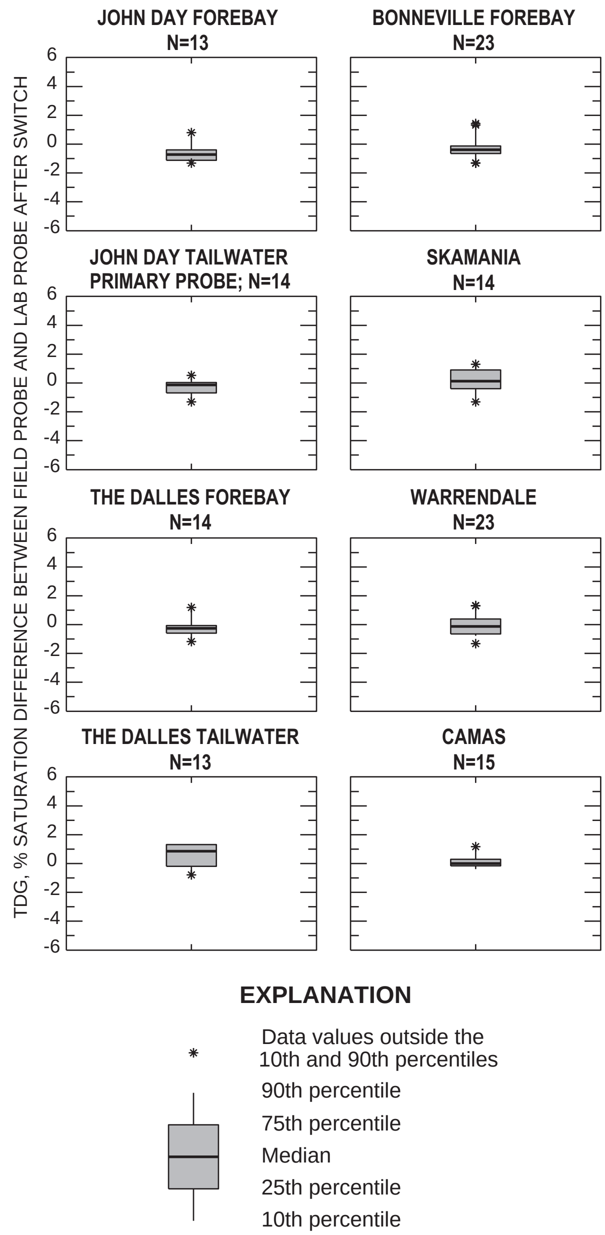

Figure 8. Total dissolved gas difference between the field probe and lab probe at the end of field calibrations.

Daily Quality-Assurance Checks

Each morning, the performance of the TDG fixed stations was evaluated and e-mail concerning the status of the network was sent to involved parties, including USACE. Figures 9–11 are examples of the materials used for the daily quality-assurance checks. Figure 9 shows a checklist summarizing intersite comparisons. Figure 10 is an example of 1 of 33 pairwise graphs of TDG, barometric pressure, and temperature data from adjacent sites made during the spring and summer spill season; 1 additional graph showed the 2 TDG measurements made at the John Day tailwater site. Data for graphs of intersite comparisons were from the USGS ADAPS database, current to approximately 0600 hours on the day of the check. Also included were data from the USACE Web site showing spill and total flow below the dams at John Day, The Dalles, and Bonneville. These data were included to help explain variations of TDG that could be related to the changing operations of the dams above the fixed-station TDG monitors. For example, figure 11 illustrates the effects of changes in spill over the John Day Dam on TDG measured at the John Day tailwater site.

These quality-assurance materials were valuable for evaluating the status of the monitoring network. If data were completely missing from one site, the satellite downlink data were checked to see if signal strength, transmission time, or battery voltage data were anomalous for previous transmissions.

On occasion during these daily checks, the TDG values were observed to suddenly increase and stay constant at a larger value, without a corresponding increase in spill at the dam above the site. In these cases, the problems were caused by a tear or hole in the TDG membrane, which allowed water pressure to influence the TDG sensor, which should have been exposed only to the air inside the tubular TDG membrane.

When this happened, an “emergency” field trip was made to resolve the problem. In the case that there were data from a site that were known to be incorrect as a result of a damaged membrane or for any other reason, this was noted in the daily e-mail to the interested parties mentioned previously.

CHECKLIST FOR TDG DAILY CHECKS - attach to daily graphs

Date 6/23/00 Checked by Tanner

Check the 33 intersite comparison graphs back to the last day checked.
(For example, check back to Friday on Monday).

✓ Pt - No more than 25% of the hourly values are missing or anomalous
(Intersite comparisons differ < 20 mm Hg unless spill explains difference)

✓ B.P. - No more than 25% of the hourly values are missing or anomalous
(Intersite comparisons differ < 14 mm Hg)

If these conditions are not met, an emergency trip needs to be taken within the next 48 hours.

✓ Temp. - Check for intersite variations > 2.0 deg C, note to COE, but
no emergency trip is needed.

Y or N Is replot needed to clearly see data variations on any plot?
If yes - replot data and put the new plot with the daily check.

Y or N Are any data missing from ADAPS but present at COE website?
If yes - put COE data with site file.
- immediately contact our computer section to restore data to ADAPS if possible.

Y or N Were any graphs marked to explain or note any potential anomalies?
If yes - make a copy and put copy in site file.

X Send email to COE describing site status, including planned emergency trips.

If any site is other than satisfactory, include the hour of missing or questionable data, and put a copy of the email in site file.

Figure 9. Checklist for total dissolved gas daily quality-assurance checks.

Data Workup and Archive

Periodically, and at the end of the fiscal year, data for each TDG fixed-station were reviewed in-house and documented on paper files and in the USGS database. Tables and graphs of hourly value data were prepared for TDG, barometric pressure, and water temperature for each month for which data were collected. These tables and figures were screened using intersite comparisons between adjacent sites and monthly graphs of spill from appropriate dams. Any incorrect data were deleted from the database. Common causes of incorrect data included elevated TDG measurements due to torn TDG membranes (mentioned above) and missing value codes from the satellite transmissions that were interpreted by the USGS database as large measured values. An electronic file of data to be deleted was prepared for USACE.

In one case, at the Skamania site from August 30 to September 15, 2000, a linear shift was applied to the TDG data due to the gradual failure of the TDG sensor. The shifted data were incorporated into the USGS database and the same shifted data were supplied to USACE.

Ancillary data and information were also documented in paper files. Data for battery voltage after each satellite transmission were graphed on a monthly basis in order to track any problems with data transmission

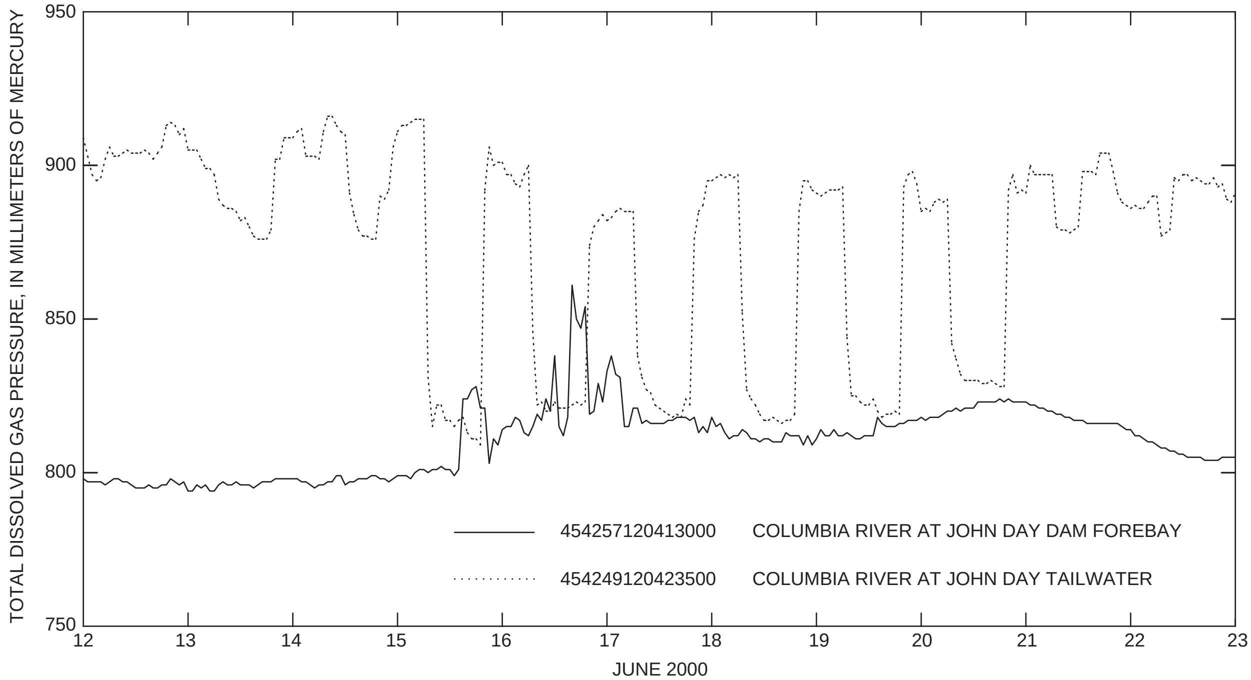

Figure 10. Total dissolved gas pressure above and below John Day Dam.

TOTAL DISSOLVED GAS REPORT FOR JOHN DAY TAILWATER
starting at 0405 22 jun 2000

DATE	TIME	WA TM DEG F	BARO PRES	TD1 GAS PRES	TD2 GAS PRES	GAS(1) %	SPILL S	TOT R
0622	0500	62.7	760.0	897.0	890.0	118.03	090.4	153.5
0622	0600	62.7	759.0	897.0	888.0	118.18	083.4	147.6
0622	0700	62.7	760.0	880.0	879.0	115.79	054.3	160.6
0622	0800	62.7	760,0	879.0	875.0	115.66	054.2	176.7
0622	0900	62.8	761.0	879.0	874.0	115.5l	054.2	181.7
0622	1000	62.8	761.0	878.0	873.0	115.37	054.3	185.8
0622	1100	62.8	759.0	879.0	873.0	115.81	058.7	194.9
0622	1200	62.9	760.0	880.0	873.0	115.79	063.9	211.7
0622	1300	62.9	759.0	898.0	887.0	118.31	070.3	230.4
0622	1400	63.0	759.0	898.0	892.0	118.31	070.3	264.1
0622	1500	63.1	760.0	898.0	891.0	118.16	070.5	236.0
0622	1600	63.1	760.0	897:0	891.0	118.03	073.4	235.0
0622	1700	63.1	759.0	904.0	896.0	119.10	081.4	275.8
0622	1800	63.1	760.0	904.0	896.0	118.95	083.0	274.7
0622	1900	63.1	759.0	904.0	895.0	119.10	084.0	264.4
0622	2000	63.1	760.0	898.0	891.0	118.16	136.8	233.5
0622	2100	63.2	761.0	891.0	882.0	117.08	122.2	209.8
0622	2200	63.2	761.0	888.0	880.0	116.69	122.2	207.2
0622	2300	63.1	759.0	887.0	878.0	116.86	124.5	206.8
0623	000	63.1	761.0	886.0	880.0	116.43	122.1	203.0
0623	0100	63.1	760.0	887.0	880.0	116.71	122.1	200.4
0623	0200	M	M	M	M	U	118.3	190.7
0623	0300	M	M	M	M	U	118.3	200.2
0623	0400	M	M	M	M	U	116.4	200.4

STATUS=M, data missing due to lag time between data collection and transmission
STATUS=U, data unavailable (not calculable)

Figure 11. Example data table from U.S. Army Corps of Engineers Total Dissolved Gas Reports Web page (http://www.nwd-wc.usace.army.mil/report/tdg.htm).

due to low battery voltage. The recorded probe depth was also graphed. E-mail correspondence referring to each site was also archived in the corresponding site folder.

SUMMARY OF DATA COMPLETENESS AND QUALITY

Year-end summaries of water year 2000 TDG data completeness and quality are shown in table 2. Data in this table were based on the amount of hourly TDG data and barometric pressure data that could have been collected during the scheduled monitoring season. At all stations, more data were collected than was scheduled because the monitors were set up early to ensure correct operation. Because TDG in percent saturation is calculated as total dissolved gas pressure, in millimeters of mercury, divided by the barometric pressure, in millimeters of mercury, multiplied by 100 percent, any hour with missing TDG pressure data or missing barometric pressure data was counted as an hour of missing data for TDG in percent saturation. The percentage of real-time data received shown in table 2 represents the data that were received via satellite telemetry at the USGS downlink. The USACE downlink operated independently, but the amount and quality of the data were very similar. At each station, 98 percent or more of the data were received real-time by the USGS downlink, with an overall average of 99.6 percent. Problems with the amount of real-time data received were usually due to malfunction or misprogramming of the data-collection platform.

The collection of water temperature data had fewer complications than did the collection of TDG and barometric pressure data. There were only a few hours of missing or incorrect temperature data, except for instances where all data parameters were missing due to problems with the DCP.

TDG data were considered to meet quality-assurance standards if they were within 1 percent TDG of the expected value, based on calibration data and ambient river conditions at adjacent sites. The percentage of real-time TDG data passing quality assurance is shown in table 2. The lowest percentage for a station was 95.3 percent at Skamania, but all of the missing data was eventually restored to the database. The overall average of real-time data passing quality-assurance standards was 98.5 percent. Most problems with meeting quality-assurance standards were due to membrane failure—leaking or tearing of the TDG membrane.

QUALITY-ASSURANCE DATA

Duplicate data for John Day tailwater were collected for TDG only. Data between the two instruments compared well, as depicted on figure 12, which shows how the two probes responded to daily changes in spill at the John Day Dam. The greatest differences occurred at times when gas levels changed rapidly, as a

Table 2. Total dissolved gas data completeness and quality, water year 2000
[TDG, total dissolved gas]

Abbreviated station name	Planned monitoring, in hours	Percentage of real-time TDG data received	Percentage of real-time TDG data passing quality assurance
John Day forebay	4,032	99.4	99.4
John Day tailwater			
Main probe	4,032	99.9	99.9
Duplicate probe	4,032	99.9	98.7
The Dalles forebay	4,032	99.5	97.7
The Dalles tailwater	4,032	100.0	100.0
Bonneville forebay	8,784	98.3	98.2
Skamania	4,560	100.0	95.3
Warrendale	8,784	99.9	99.3
Camas	4,560	99.8	98.0
Average		**99.6**	**98.5**

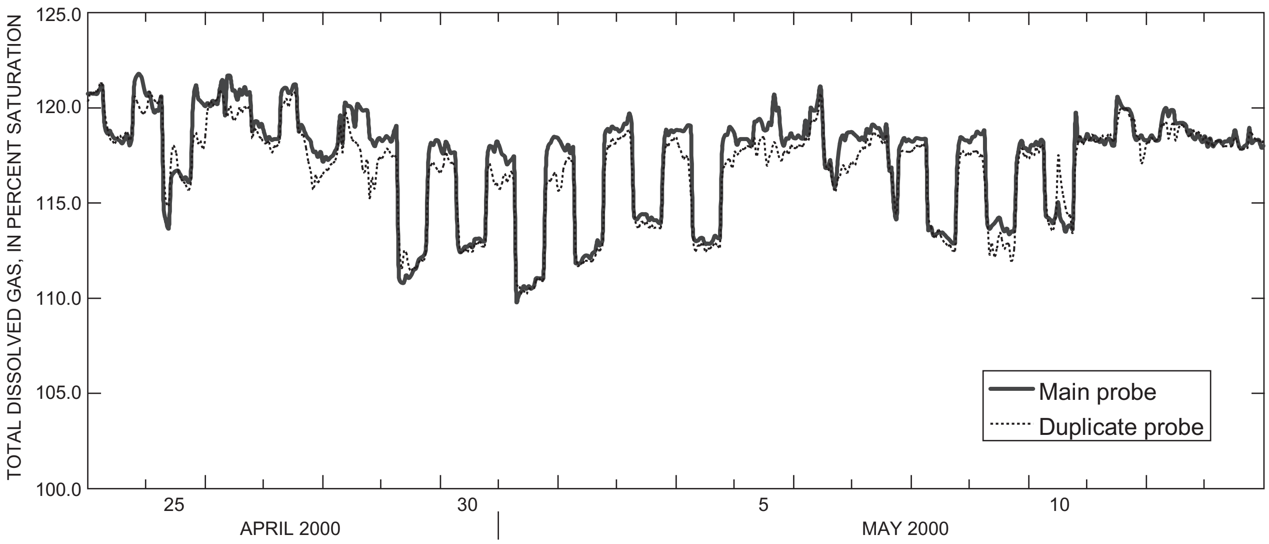

Figure 12. Selected total dissolved gas data at the main and duplicate probes at John Day tailwater.

result of each probe responding at a different rate. Future deployment of redundant probes should have paired membranes with the same age and use, to reduce differences in response time.

A slight bias existed between the two probes as depicted by figure 13, which represents 4,317 hourly values from March 23 to September 18, 2000. The duplicate probe was 1 foot higher in the water column and tended to read lower than the main probe. A likely cause of this bias may be a reduced flow over the membrane on the duplicate probe. Perforations in the housing were originally intended for one probe located at the end of the housing. This concern will be eliminated by installing two adjacent TDG sensors on the same Hydrolab.

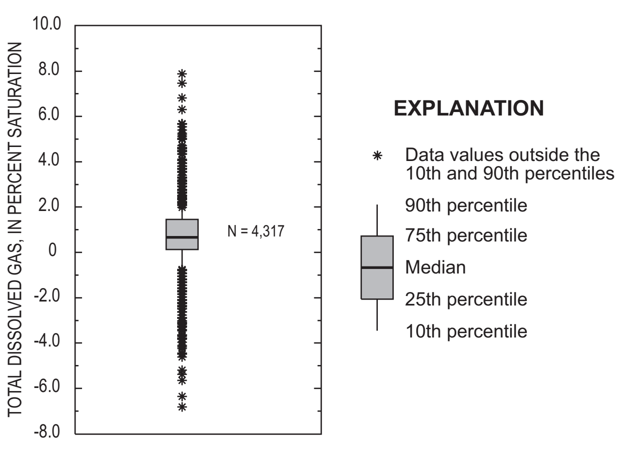

Figure 13. All of the total dissolved gas data at the main and duplicate probes at John Day tailwater.

Duplicate TDG and water temperature data were collected at the John Day forebay from 4/5/2000 at 1600 hours to 4/12/2000 at 1400 hours. The duplicate probe was mounted approximately 6 feet horizontally from the main probe at the same depth. The duplicate data were collected to confirm the rapid changes in temperature and TDG above the John Day Dam that did not occur below the dam, as depicted in figures 14 and 15. TDG and water temperature measured by the main probe compared well with the duplicate probe. Based on the strong correlation between the two units, the rapid changes in water temperature and TDG appear to be real and not a problem with instrumentation. The cause of these rapid changes is not known at this time; however, it is suspected that water near the probes is not well mixed and occasionally water in the vertical section is transported across the face of the dam by certain spill patterns that cause poorly mixed water to flow over the probes.

SITE-SPECIFIC CONSIDERATIONS

Even though the same type of electronic equipment and instruments were used at each site, there were differences among the sites in the physical setup and environment of equipment. Some sites were at a river location with limited depth, some had greater circulation of water past the probe, and some were prone to damage by insects. These site-specific considerations are summarized below for each of the eight sites.

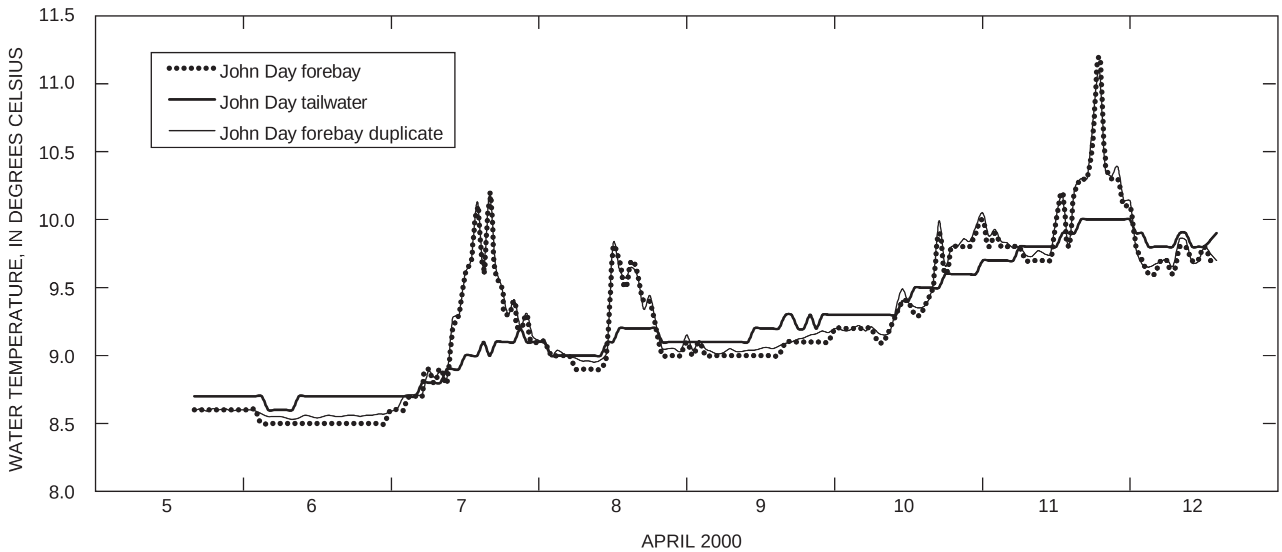

Figure 14. Duplicate water temperature data at John Day forebay and water temperature data at John Day tailwater.

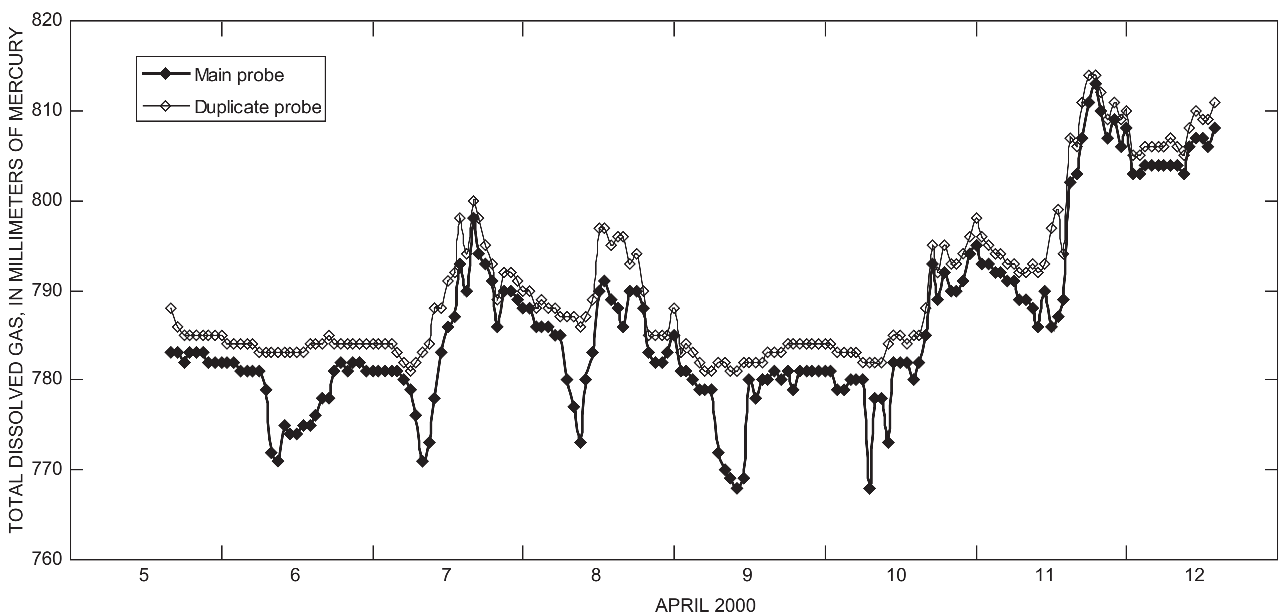

Figure 15. Duplicate total dissolved gas data at John Day forebay.

Camas

At the Camas site, there were three separate occasions (June 29, July 23, and July 31, 2000) when the TDG membrane was pierced by aquatic insects, which were observed inside the probe housing. When this happened, the hole in the membrane allowed water pressure instead of dissolved gas pressure to act on the TDG pressure sensor. As a result, the measured values for TDG rose suddenly to about 1,000 mm Hg, even though there was not an unusual amount of spill from Bonneville Dam, which is upstream of the Camas site. This condition was diagnostic of a broken membrane, and accordingly, an emergency field trip was made to replace the probe with a newly calibrated probe. During the third trip due to a damaged membrane, screening was added to the probe to exclude insects, and the problem did not reoccur. TDG data that were lost due to this type of damage were not recoverable because there is no way to know precisely what would have been recorded at those times.

Also at the Camas site, the barometer was adjusted incorrectly, resulting in a bias of -5 mm Hg for 21 hours beginning on June 5, 2000, at 1200 hours. The barometer was readjusted, and the 21 hours of data were corrected in the database.

Skamania

At Skamania, a newly calibrated probe was placed in the river on August 30, 2000, at 1036 hours. The following day, scheduled spill ended for the season at Bonneville Dam, just upstream. As a result, the TDG was expected to decrease at the Skamania site, and a decrease was observed. However, the TDG eventually decreased to levels lower than would be expected. When the probe was inspected, it was found to have a faulty sensor, which accounted for the TDG readings being too low. Subsequently, a linear shift was applied to the data, with no shift for August 30 at 1100 hours, and shifts increasing until a final shift of +56 mm Hg on September 18 at 1100 hours. This was an example of data being transmitted in a real-time manner, but not being correct. Further, in this case, the data were correctable because the gradual decline in TDG readings (with no change in spill) was consistent with a gradually failing TDG sensor.

Warrendale

At Warrendale, there was a faulty TDG sensor, which resulted in erratic TDG values from February 29, 2000, at 1300 hours until March 2, 2000, at 0800 hours. The sensor was replaced, but there was no way to correct the data in question, so it was deleted from the database.

Compensation depth for TDG measurement is the depth above which degassing will occur. In order to measure TDG accurately, the probe must be deeper than the compensation depth, which is calculated as [TDG pressure, in millimeters of mercury, minus barometric pressure, in millimeters of mercury] divided by 23 (a constant). This equation was based on a formula derived from Colt (1984, page 104). If the probe is above the minimum compensation depth, the measured TDG may be less than it would be if measured at a greater depth.

The compensation depth can be calculated for any given percent saturation of TDG if an assumption is made for the barometric pressure. For example, if the barometric pressure is assumed to be 760 mm Hg, and the TDG level is 120%, the TDG pressure would be 912 mm Hg (120% of 760 mm Hg), and the compensation depth would be [912 - 760]/23 = 6.6 feet. Using the same assumption for barometric pressure, at a TDG level of 145%, the compensation depth would be 14.9 feet. Where possible, the TDG probes were kept at a depth of 15 feet or greater.

Warrendale was the only site where the TDG probe was above the compensation depth at any time in water year 2000. After the end of the spill on August 31, 2000, the river stage had dropped, but supersaturated water remained in the river from upstream dams, resulting in the probe depth being above the compensation depth for several days (fig. 16). This was because of the physical characteristics of the site. The instruments were housed on a floating wooden dock, and the TDG probe was suspended from the dock. When the river was shallow at the Warrendale site, as it was in early September, the probe depth was about 4 feet because that was the total depth of the river below the dock at the time. In order to measure TDG at a greater depth, the probe would need to be moved to a deeper part of the river, but that was not possible because of the fixed location of the site.

Bonneville

At the Bonneville site, there were data transmission problems from January 1 to January 5, 2000, resulting in 46 hours of missing real-time TDG data. The cause of this missing data is unknown, but it may have been due to large cranes that work in the dam area, which have been known to sometimes be placed between the DCP antenna and the orbiting satellite, thus occluding the satellite. These 46 hours of TDG data were restored to the permanent database using the data logged onsite by the DCP.

From July 21 to July 25, 2000, 91 hours of data were missing from the Bonneville site due to failure of the DCP. In this case, the data were not logged onsite, so it was not possible to restore the data to the database.

The Dalles Tailwater

Only 2 hours of TDG data were missing from The Dalles tailwater site. One datum was missing due to calibration activities on July 20, 2000, and the cause of loss of the other datum is not known.

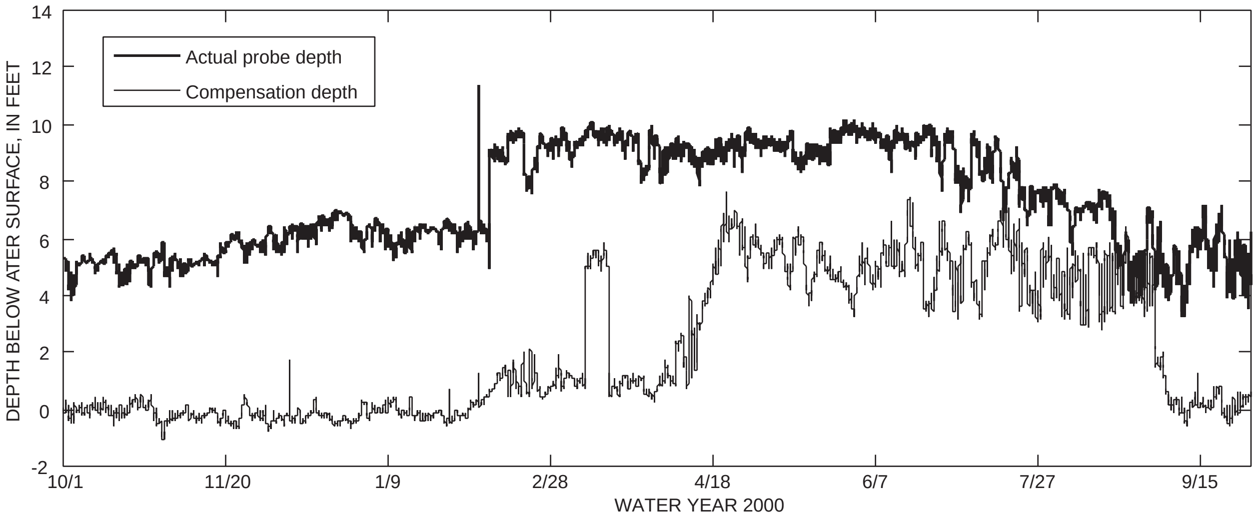

Figure 16. Compensation depth and actual probe depth at Warrendale.

The probe housing at The Dalles tailwater site is strapped to anchors along a slope of rock rip-rap. On several occasions during the monitoring season, the probe housing was raised or lowered according to the river stage. In this manner, it was possible to maintain the probe depth below the minimum compensation depth.

The Dalles Forebay

TDG data were missing from The Dalles forebay site for a 72-hour period from April 15 to April 18, 2000, due to a ruptured TDG membrane. It was not possible to restore these data to the database.

DCP problems from August 29 to September 5, 2000, were the cause of 19 hours of data that were missing in real-time. These data were later restored to the database from the data logged onsite by the DCP.

John Day Tailwater

For the duplicate unit at the John Day tailwater site, 45 hours of TDG data were missing from September 4 to September 6, 2000, due to a rupture or tear in the TDG membrane. These data could not be restored. There were only 3 hours of missing TDG data for the main unit at John Day tailwater.

John Day Forebay

Beginning on August 3, 2000, 23 hours of TDG data were missing from the John Day forebay site due to an error in reconnecting the electronic barometer during a routine calibration. These data could not be restored to the database.

On several occasions at the John Day forebay, the TDG value was observed to suddenly rise 10 or 20 mm Hg for several hours for no apparent reason. It was noted that the water temperature also rose during these times. These excursions of TDG and water temperature were observed on hot, sunny days, and it is believed that a parcel of heated water was drawn past the submerged TDG probe during spill, causing the increase in water temperature. The TDG measured at the probe would be expected to also increase, because when a gas is heated and the volume is fixed (as it is inside the TDG membrane), the pressure of the gas will increase.

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US Army Corps
of Engineers®
Walla Walla District

Quality Assurance and Quality Control for Total Dissolved Gas Monitoring - Lower Snake River, Washington; Clearwater River, Idaho; and Columbia River, Oregon and Washington, 2000

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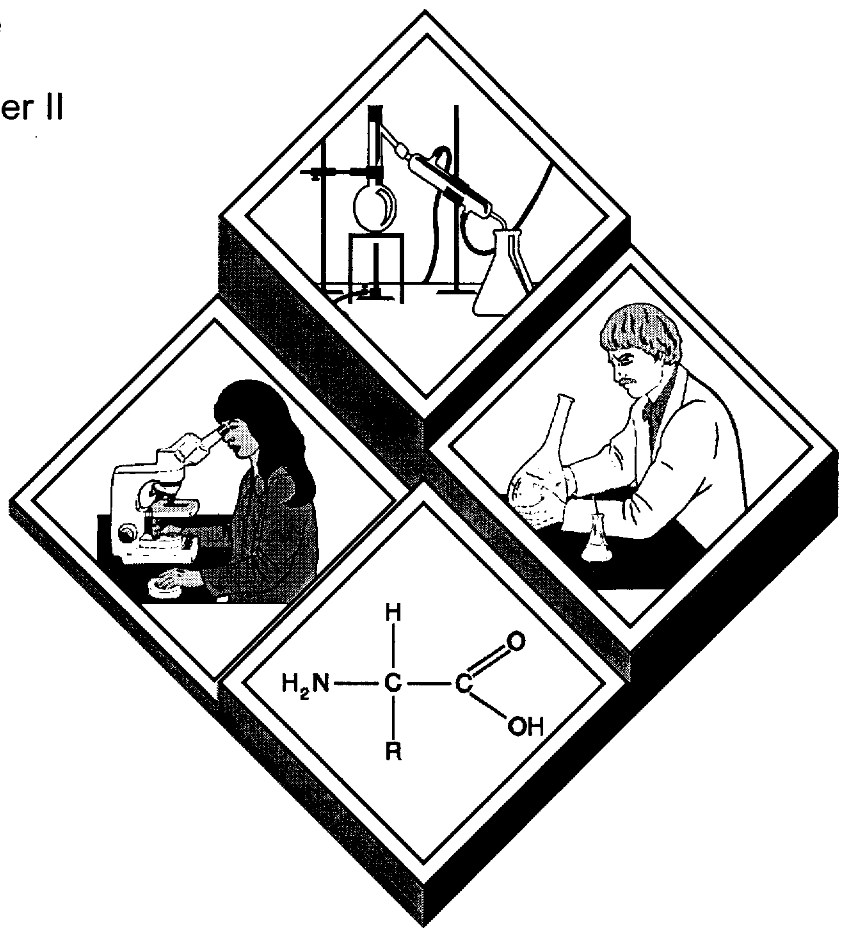

February 2001

QUALITY ASSURANCE AND QUALITY CONTROL FOR TOTAL DISSOLVED GAS MONITORING - LOWER SNAKE RIVER, WASHINGTON; CLEARWATER RIVER, IDAHO; AND COLUMBIA RIVER, OREGON AND WASHINGTON

February 2001

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Gary Slack
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Thomas D. Miller II

ABSTRACT

The U.S. Army Corps of Engineers Walla Walla District (CENWW) operates 16 monitoring stations for monitoring total dissolved gas (TDG) in the Columbia, Snake, and Clearwater Rivers. Each station transmits this hourly data via the Geo-stationary Operational Environmental Satellite (GOES) system every 4 hours to the Corps of Engineers Northwestern Division (CENWD) in Portland, Oregon. The data is stored in the Columbia River Operational Hydromet Management System (CROHMS) database. In Fiscal Year (FY) 2000, the district [with cooperation from HDR Engineering and the United States Geological Survey (USGS) in Pasco, Washington] installed improved equipment and new data collection platforms (DCP's). This year's focus was on maximizing sonde reliability and precision. A rigorous Quality Assurance/Quality Control (QA/QC) program was initiated to determine the absolute precision of measurement and repeatability using Hydrolab Minisonde water quality sondes. The data quality objectives (DQO's) for the instruments were set at ±2 millimeters of Mercury (mm Hg) for dissolved gas pressure and ±0.2 degrees Celsius (° C) for temperature. The instrument inventory mean was calculated to be 0.25 mm Hg with a standard deviation variation (SDV) of 1.11 for gas pressure and -0.04° C with an SDV of 0.07. Improved calibration procedures and new standards accounted for the increases in accuracy. Evaluation of the performance of each field station proved far more difficult. The monthly charting processes proved to be more valuable to evaluate the problems as they occurred rather than for pure statistical use. Included in this report are the individual 28 sonde performance histories for water year 2000 and each station performance description, including the monthly charts. Appendix B includes the pertinent quality data used to produce this report and appendix F provides high detail maps produced from 7.5-minute quad sheets with pinpoint locations of each TDG monitoring site.

INTRODUCTION

The CENWW operates six multi-purpose dams in the Columbia River, Lower Snake River, and Clearwater River Basins. These facilities cover a total calculated drainage area of over 214,000 square miles of the Pacific Northwest and provide flood control, navigation, irrigation, recreation, hydropower, fish and wildlife habitat, and municipal and industrial water supply. During spring runoff, air is entrained with plunging flows over the spillways and is carried deep into the spillway's stilling basin where water pressure causes the air to dissolve. Beyond the stilling basin, the river becomes shallow and the water becomes supersaturated. The U.S. Environmental Protection Agency (USEPA) has established an upper limit of 110 percent saturation for protection of freshwater aquatic life. Concentrations above this level can cause gas bubble trauma in fish and adversely affect other aquatic organisms (USEPA, 1986). Spillway deflectors have been installed on all dams in the area served by CENWW to reduce the plunging depths of spillway flows during normal water years. The Corps minimizes spring stream flows in the region to reduce the production of TDG and to save water for summer needs. The CENWW collects real-time TDG data (available within about 4 hours of current time) upstream and downstream from its dams in a network of fixed station monitors known as the Total Dissolved Gas Monitoring System (TDGMS).

Background.

Real-time TDG data are vital for dam operation and for monitoring compliance within state and Federal guidelines and regulations. The data is used by water management personnel from the Walla Walla and

Portland offices of CENWD to maintain favorable water quality conditions, facilitate fish passage, and improve survival in the Federal Hydropower System. HDR Engineering (HDR), under contract DACW-00-D-001 with CENWW, collected hourly TDG and related data in the Mid-Columbia, Lower Snake, and Clearwater Rivers from 16 TDGMS sites. Since 1996, CENWW has maintained a data collection system with increasing levels of QA and QC. In conjunction with HDR, they provided most of the technical innovation currently used by all Federal, state, and local entities. However, data collection methods and QA plans have changed significantly since 1996. In water year 2000, improved TDG/temperature probes and new methods of calibration in the laboratory were used. In addition, hourly data for water year 2000 were corrected or deleted to reflect measurements made during instrument calibration.

Purpose and Scope.

The purpose of gas monitoring is to provide managers, agencies, and interested parties with near real-time data for managing stream flows and TDG levels downstream from Federal dams. As with any data collection activity, an important component that cannot be overlooked is the quality of the data. Measurement of data quality allows determination of the usefulness and relevance to their current and future decision processes. This report describes the data collection methods and evaluates QA data for the TDGMS that includes the McNary, Ice harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs. Additionally, this system provides water quality data for the Clearwater River downstream of Dworshak Dam, the Columbia River near Pasco, and the Snake River near Anatone, Washington (see figure 1 and table 1). This report is designed to document data quality of the TDGMS for water year 2000. Measurements include TDG pressure, barometric pressure, and water temperature at 16 sites.

Acknowledgments.

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METHODS

Instrumentation.

Instrumentation at each fixed station consists of a multi-parameter water quality sonde, an electronic barometer, a DCP, and either a 120 volt alternating current (VAC) or 12 volt direct current (VDC) power supply. The water quality sonde currently in use is the Hydrolab® Corporation Minisonde® 4 or Minisonde 4a. The sonde has individual sensors for TDG, temperature, and dissolved oxygen (DO). The TDG sensor membrane consists of a cylindrical framework wound with a length of Silastic (dimethyl silicon) tubing. The tubing is tied off at one end and the other end is connected to a mechanical pressure transducer. After the TDG pressure in the river equilibrates with the gas pressure inside the tubing (about 15 to 20 minutes), the pressure transducer measures a potentiometric voltage that is converted to mm Hg electronically. Thus, a point measurement of the TDG pressure in the river is then transmitted digitally to the DCP. The water temperature sensor is a thermocouple. The barometer was manufactured by Honeywell and is a PPT model [14 pounds per square inch (psi)] precision pressure transducer connected to analog channel 4 on the DCP. The sonde is connected by a heavy-duty, weatherproof cable into the SDI-12 channel of a Sutron® Model 8210 DCP. The DCP has three basic functions: sensor interfacing, data storage, and data transmission to the GOES system (Jones et al., 1991). Most of the stations use a crossed Yagi antenna connected to the DCP using a coaxial cable with the antenna mounted on a mast to provide transmission to the GOES system. Due to continuous vandalism problems at the Pasco levee and McNary tailwater stations, a "Top-hat" antenna is used.

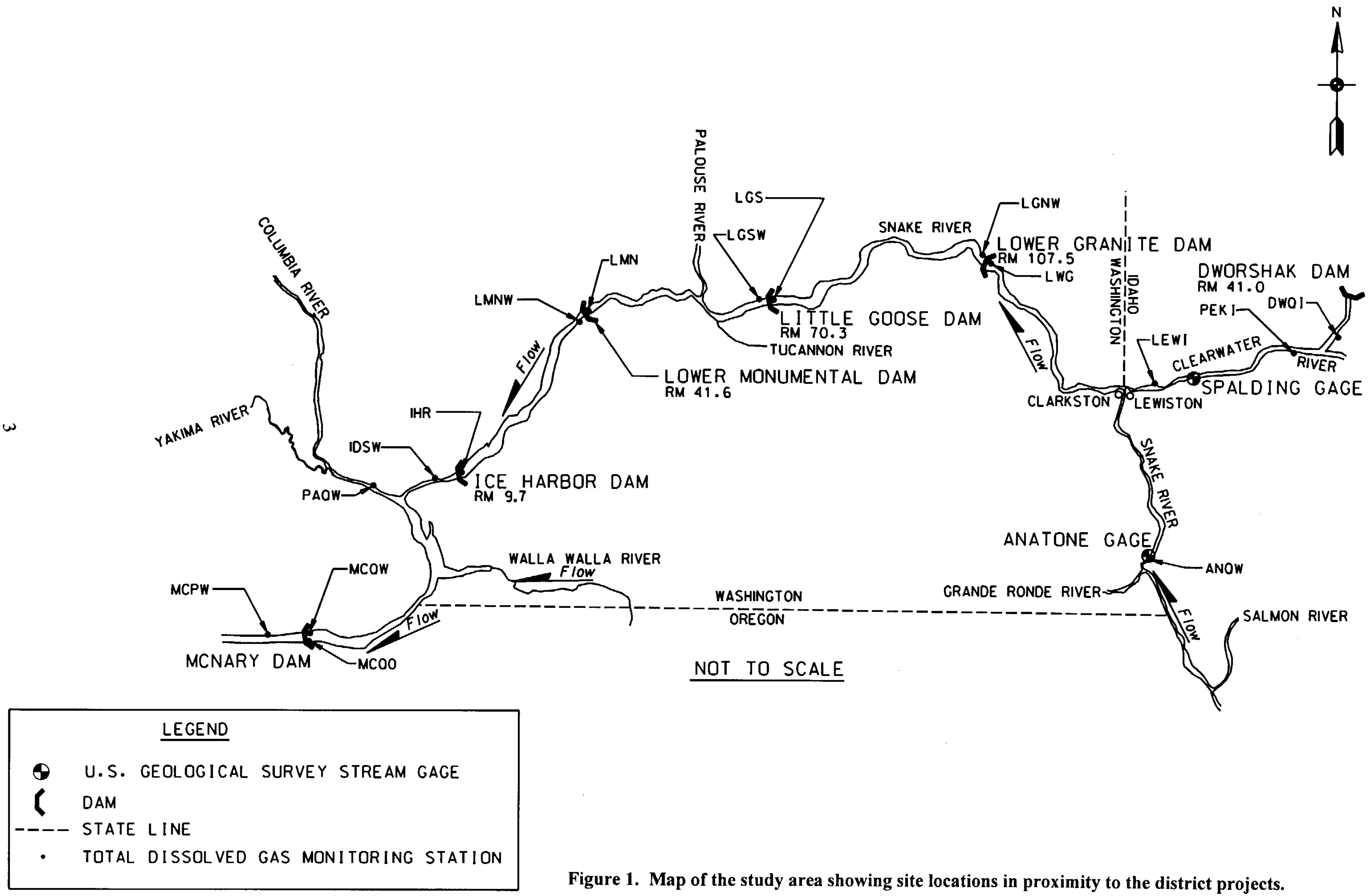

Figure 1. Map of the study area showing site locations in proximity to the district projects.

Station Letters	Date Est	River Name	River Mile	Description	Latitude	Longitude	Project	Drainage Area	Quad Map Name
ANQW	1998	Snake River	167.5	Left Bank	460550	1165836	LWG	92,960 sqm	Limekiln Rapids, Idaho
DWQI	1994	NF Clearwater River	40	Left Bank	463011	1161918	DWR	2,440 sqm	Ahsahka, Idaho
IDSW	1990	Snake River	6	Right Bank	431432	1185620	IHR	109,000 sqm	Humorist, Washington
IHR	1984	Snake River	10	Mid-River	461458	1185242	IHR	109,000 sqm	Levey SW, Levey, & Slater Washington
LEWI	1996	Clearwater River	4	Right Bank	462606	1165736		93,400 sqm	Lewiston Orchard North, Idaho
LGNW	1990	Snake River	107	Right Bank	463958	1172618	LWG	103,500 sqm	Almota, Washington
LGS	1984	Snake River	70	Mid-River	463505	1180132	LGS	103,900 sqm	Starbuck East, Washington
LGSW	1990	Snake River	69	Right Bank	463459	1180231	LGS	103,900 sqm	Starbuck East, Washington
LMN	1984	Snake River	42	Mid-River	463347	1183214	LMN	108,500 sqm	Lower Monumental Dam, Washington
LMNW	1990	Snake River	41	Left Bank	463313	1183251	LMN	108,500 sqm	Lower Monumental Dam, Washington
LWG	1984	Snake River	108	Left Bank	463933	1172530	LWG	103,500 sqm	Almota, Washington
MCPW	1990	Columbia River	291	Right Bank	455600	1191930	MCN	214,000 sqm	Umatilla, Oregon-Washington
MCQO	1986	Columbia River	292	Left Bank	455558	1191743	MCN	214,000 sqm	Umatilla, Oregon-Washington
MCQW	1985	Columbia River	292	Right Bank	455625	1191747	MCN	214,000 sqm	Umatilla, Oregon-Washington
PAQW	1998	Columbia River		Left Bank	461332	1190725	MCN	103,000 sqm	Pasco, Washington
PEKI	1996	Clearwater River	36	Left Bank	463226	1162331	DWR	8,040 sqm	Southwick, Idaho

Table 1. Description and Locations table of the 16 TDGMS stations.

At all 16 stations, the DCP controls the supply of power to the barometer and the water quality sonde. All DCP's are powered directly by an 86 ampere-hour, 12-volt gelled-electrolyte battery manufactured by Deka®. The battery was charged by a regulated voltage circuit from a 12 VDC, 30-watt solar panel regulated by a Sunsaver® model (6 or 10) LVD power controller or a 120 VAC trickle charge system manufactured by Coastal Environmental Systems®. The DCP is programmed to record and transmit five parameters: barometric pressure (in mm Hg), TDG pressure (in mm Hg), DO [in milligrams per liter (mg/L) and % saturation], water temperature (in ° C), and battery voltage (in volts). Battery voltage is monitored to ensure that the instrumentation receives adequate power. The data for each parameter is logged electronically every hour, on the hour, and stored in the DCP memory. Every 4 hours, the DCP transmits the most recent 8 hours of logged data to the GOES satellite. Consequently, each piece of data is transmitted three times to protect against data loss. The GOES satellite retransmits the data to a direct readout ground station at Wallops Island where it is automatically decoded and retransmitted to the DOMSAT system. A satellite downlink automatically transfers the data to the CROHMS database located in Portland, Oregon. During the fixed station calibration visits, the DCP stored data can be downloaded to a Rocky 2000® computer. When it is necessary to fill in any real-time data lost during satellite transmission, data is sent via e-mail to our division office in Portland, Oregon.

The same type of instrumentation was used at each of these 16 stations but installations, locations, and river conditions near the instruments differed according to site. Notably, stations above and below dams recorded either slow-moving stratified water or well-mixed higher-velocity water. In all cases, stations were subject to daily fluctuations in river flow as turbines and spillway gates were periodically opened and closed.

Each instrument package is installed in a 4-inch-diameter PVC pipe mounted in a convenient but unobtrusive location. Forebay stations are attached to the face of the dam by clamps. Tailwater and river stations are laid on the bank and anchored to large blocks of concrete a few feet below water. The instrument is inserted and withdrawn by use of a small rope looped over a bolt at the submerged end of the pipe. This usually works well but, occasionally, river debris, mechanical damage, or fluctuating water levels interfere with normal operation.

The Dworshak tailwater station has a dual communications package and is configured to send 15-minute data to the powerplant operator to assist in operation of the Francis turbine air injection system. The data is then sent through the GOES systems on the 4-hour time hack with hourly data like the rest of the DCP's. The special 15-minute data is sent directly to the powerplant operator controls and is not available for outside use beyond the project control room.

Calibration of Instruments in the Laboratory.

Active sondes are calibrated on a 2-week cycle. The general procedure is to check the operation of the probe deployed at the station without disturbing it, replace the in-place probe with one recently calibrated in the laboratory (QA/QC probe), and then to check the operation of the newly deployed probe. The details of the laboratory calibration procedures are as follows.

The TDG sensor requires an actual two-step calibration procedure. This means that adjustments are made at two intervals in the calibration curve in order to calibrate the sensor. The base calibration point is referred to as Base TDG and the pressurized calibration point corresponding to pressurized TDG pressure. For TDG sensor calibration, the base point is equal to the atmospheric pressure at the time of calibration as measured by a weather service type, wall-mounted mercury barometer. The pressure point is equal to the barometric pressure plus a standard value that is chosen to create a calibration curve with a range that will include the range of TDG values expected to be measured in the field by the sensor. In most cases, the pressure point is equal to the barometric pressure plus 200 or 300 mm Hg. This creates a slope capable of interpolating the full range of expected field values. Pressure calibrations were done using a Hiese® digital pressure calibrator, which is certified according to standards of the National Institute of Standards and Technology (NIST). The end of the TDG probe containing the sensors was put in a plastic pressure chamber and the pressure was increased 200 mm Hg above the ambient barometric pressure.

The TDG membrane is cleaned with a squirt bottle of tap water then tested for leaks using soda water. If the membrane does not have a leak, it is removed from the sensor and air-dried for at least 72 hours. The TDG sensor is also air-dried at room temperature for at least 24 hours since water sometimes collects inside the tubular membrane due to condensation. If the condensation is not removed, it can slow the equilibration of air pressure between the outside of the membrane and the TDG sensor.

Each sonde contains a thermister for recording and reporting water temperature. The results are reported in ° C. Sonde thermisters are all factory calibrated. We do not make adjustments to the temperature sensor calibration. Therefore, the only measure thermister performance was by comparing the reading to an approved National Biological Survey (NBS) mercury thermometer standard. Sondes with thermisters that proved to be errant or erratic in performance were taken out of the active inventory and shipped to the manufacturer for repair and calibration.

A DO probe measures the amount of oxygen present in water and is used by the system operators to make quality checks on the data and as a surrogate to measure instrument competency. The Sonde reports the DO results in percent (%) and mg/L. The method for calibrating the DO sensors has not yet been selected for the standard operating procedures (SOP's), but instruments are calibrated every 2 weeks using the manufacturer's published procedures. In most cases, the calibration is conducted using saturated air or azide modified Winkler titration.

Barometric pressure is used as a standard for calibrating the TDG and DO sensors. It is also an important value used in calculating the percent of TDG saturation. HDR maintains performance records for the wall-mounted mercury barometer located at HDR, the Surveyor 4 instrument used for fieldwork, and the Honeywell barometers at each station. Calibration data is also maintained for the Surveyor 4, which is the only barometric pressure-sensing device that can be calibrated by our personnel.

Performance Data.

It is important to recognize the difference between calibration data and performance data. *Performance Data* is collected each time a sensor is compared to its standard or when two instruments are compared at a given station. These values represent the measured difference between two readings and are keyed with the term *Delta.* Delta values mirror the ± variation of sensor or instrument readings from their respective standard. For example, a negative value indicates that the sensor or instrument was reading below its respective standard. Appendix A contains an example of the data entry form used to make QA/QC calculations.

Calibration Data.

Calibration procedures only take place after recording the performance data described above. *Calibration Data* reflects the actual adjustments that take place when a sensor is calibrated to correct for drift. These values are keyed with the term *Adjustment* because they represent an actual adjustment to the calibration curve. A positive adjustment indicates that the sensor was reading below the standard (equivalent to a negative performance value) and required a positive adjustment. Adjustment and Delta values will always have opposite signs but should be the same number. The datasheets used in collecting the QA/QC information and used to document the calibration measure were then put into the ACCESS database for the calculations and compilation of the QA/QC reports.

System- and Inventory-Wide Charting and Calculations.

Each month, the data collected from all of the stations are combined to evaluate “System-Wide Station Performance.” Likewise, all of the instrument data points collected in a single month are combined to evaluate the “Inventory-Wide Sonde Performance.” This allows us to see if the control limits are being met and gives us the opportunity to identify trends in the data that may indicate possible problems in the system that may not be apparent when looking at an individual data point. If the signature of a previously encountered problem can be identified, preventive measures can be taken to resolve the issue and avoid a potential system audit.

Monthly sonde charts evaluate the *performance* data for the entire population of TDG sensors and thermometers, combined. Delta values are calculated for each parameter by subtracting the appropriate standard from the observed pre-calibrated sensor reading collected during instrument calibration. Once the delta values are calculated, they are averaged on a monthly basis to calculate a monthly mean delta value for each parameter. The standard deviation is also calculated for each parameter on a monthly basis. The following equations summarize the above description.

Delta Base TDG = [Pre-Calibrated Base TDG] - [Atmospheric Pressure]
Delta Pressure TDG = [Pre-Calibrated Pres. TDG] - [Pressurized Standard]
Delta Temperature = [Sonde Temperature] - [NBS Standard Temperature]
Monthly Mean Delta for parameter X
= [Sum of Deltas for X] / [n] where n = number of delta values for parameter X from entire sonde inventory
Standard Deviation = ± variation around the mean for [n] of X in a given month

The monthly sonde charts display the monthly mean deltas plotted for each parameter versus time (calibration date). Each graph represents one parameter and contains one data point per month. The standard deviation is represented on the graph as y-error bars for each corresponding point. The monthly sorted sonde performance data are presented in appendix B.

The performance of a station is measured by comparing two instruments at a given station at the same time, then subtracting the QA/QC sonde (standard) readings from the in-place instrument readings to calculate the delta values for TDG, DO, and temperature. The QA/QC sonde is considered the standard because, of the two instruments being compared, it was the one most recently calibrated in the lab. The Honeywell barometers at each station are also evaluated by subtracting the Surveyor 4 readings from the station barometer readings. Once the delta values are calculated, they are averaged on a monthly basis to calculate a monthly mean delta for each parameter. The standard deviation is also calculated for each parameter on a monthly basis. The following equations summarize the above description.

Delta TDG = [In-Place Sonde TDG] - [QA/QC Sonde TDG]
Delta DO mg/L = [In-Place DO mg/L] - [QA/QC DO mg/L]
Delta Temperature = [In-Place Temperature] - [QA/QC Temperature]
Delta Bar = [Station Honeywell Bar] - [Surveyor 4 Bar]
Monthly Mean Delta for parameter X
= [Sum of Deltas for X] / [n] where n = number of delta values for parameter X from entire system of stations
Standard Deviation = ± variation around the mean for [n] of X in a given month

The monthly station charts display the monthly mean delta values plotted for each parameter versus time (deployment date). Each graph represents one parameter and contains one data point per month. The standard deviation is represented on the graph as y-error bars for each corresponding point. The monthly sorted station performance data are presented in appendix C.

Sonde- and Station-Specific Charting and Calculations.

Each of the deployment stations and instruments is evaluated individually to determine which, if any, of these components may be malfunctioning. The TDG sensor *calibration* data and thermometer *performance* data for each instrument are plotted versus time (calibration date) in order to evaluate "Sonde-Specific Performance." Likewise, the station comparison data collected at individual stations are plotted to evaluate "Station-Specific Performance."

A performance chart represents each instrument with sufficient data. The chart contains thermometer *performance* data and TDG *calibration* data. The Base and Pressure *Net Cumulative TDG Calibration Adjustment* data are also represented on the graph, each as a line. The Net Cumulative Adjustment calculation reflects the cumulative adjustments made over time to the base and offset points of a TDG sensor calibration curve. Plotting this relationship provides insight about the bias of a sensor (tendency to drift over time in a particular direction in relation to the standard).

The *Delta* calculation is performed on the temperature data because HDR does not calibrate the thermometers (no adjustments are made). An *Adjustment* calculation is performed on the TDG calibration data. The *Adjustment* value represents the magnitude and direction that the base and offset points of a TDG calibration curve are adjusted to match their respective standards. The *Adjustment* value is calculated by subtracting the pre-calibrated TDG readings from the calibrated TDG readings. The Net Cumulative Adjustment value is calculated by adding each new Base or Pressurized TDG Adjustment value to the total of the values above them in their respective columns. The following equations and an illustration summarize the above descriptions.

Delta Temperature = [NBS Temperature] – [Sonde Temperature]
Base TDG Adjustment = [Calibrated Base TDG] – [Pre-Calibrated Base TDG]
Pres. TDG Adjustment = [Calibrated Pres. TDG] – [Pre-Calibrated Pres. TDG]
Net Cum Adjustment = (Net Cum Base calculation is shown below. Same calculation is made for Pressurized TDG Adjustments).

Calibration Date	Base TDG Adj.	Net Cum Base TDG Adj.
January 1	1	1
January 14	1	2
January 28	1	3

Each of the sonde charts displays the actual delta temperature and TDG adjustment values plotted versus time (calibration date). The Net Cum calculation is represented as a line on the graph. Instrument data sorted by sonde number are presented in appendix D.

Station-specific charts are based on the delta calculations performed on the data collected for each parameter at individual stations. Again, the QA/QC sonde is used as the standard to compare TDG, DO, and temperature with the in-place instrument, while the Surveyor 4 is used as a standard for barometric pressure to evaluate the station barometers. The following equations summarize the above description.

Delta TDG = [In-Place Sonde TDG] - [QA/QC Sonde TDG]
Delta DO mg/L = [In-Place DO mg/L] - [QA/QC DO mg/L]
Delta Temperature = [In-Place Temperature] - [QA/QC Temperature]
Delta Bar = [Station Honeywell Bar] - [Surveyor 4 Bar]

Each of the station charts displays the actual delta values for each parameter plotted versus time (deployment date). Station data sorted by station name are presented in appendix E.

Data Quality Objectives.

The QC officer sets DQO's for each parameter based either on environmental regulations or manufacturer precision levels. The following DQO's were established for instrument calibration: TDG > ±2 mm Hg and temperature > ±0.10° C. The following DQO's were selected for station comparison data: TDG > ±4 mm Hg and temperature > ±0.20° C. These levels are goals as much as they are thresholds. As improvements are made to the system, these levels may be lowered to encourage continued improvement.

System Audits.

When a decreasing data quality trend or bias is recognized, a system audit is initiated to determine the root cause. The system audit begins with a ground up evaluation of the entire TDGMS for any detectable error. This error can be in instrumentation, procedure, transmission, or calculation.

RESULTS

Site-Specific Data Quality.

Records show that all stations experienced occasional short-term outages. Some of these were instrument malfunctions and some were power or transmission errors. Outages that lasted for more than 2 hours are discussed below. In addition, a brief explanation about the outlying data points is offered for each chart that contains outlying data points.

The results of the statistical analyses performed on the QA/QC data for the entire system of stations indicate that the stations performed within the upper and lower QC limits and the DQO's for most of the time.

The DQO for TDG comparison delta values is 4 mm Hg. The results of the cumulative analyses indicate that the mean delta value for the TDG comparison was 0.09 mm Hg with a standard deviation of ±2.39. The DQO for temperature comparisons at the stations is 0.2° C. The results of the cumulative analyses indicate that the cumulative temperature variance calculated for all of the stations resulted in a mean delta value of 0.00° C with a standard deviation of ± 0.07° C. This is well within the manufacturer's specifications and the district's DQO's. These results indicate that the stations are performing their task well, which is to protect the instruments while exposing them to adequate volumes of fresh sample.

Monthly Station Data

Month	Avg Delta TDG*	Stdev TDG	Avg Delta Temp**	Stdev Temp
October	nd	nd	nd	nd
November	nd	nd	nd	nd
December	nd	nd	nd	nd
January	nd	nd	nd	nd
February	nd	nd	nd	nd
March	-0.20	2.24	-0.03	0.07
April	0.59	2.39	0.00	0.08
May	0.17	2.57	0.00	0.07
June	0.29	3.16	0.01	0.08
July	-0.53	1.94	-0.01	0.07
August	0.24	1.85	-0.03	0.07
September	0.00	2.03	0.00	0.04
Cumulative	0.09	2.39	0.00	0.07

nd = No Data (statistical analyses began in March 2000)

*** results are reported in mm Hg**

**** results are reported in ° C**

Table 2. Monthly and Cumulative Mean Delta and Standard Deviation Calculations for Entire Inventory of TDG and Temperature Sensors.

a. Station ANQW - Snake River at Anatone, Washington.

The Anatone station is on the left side of the river at river mile (RM) 167.5. The station operated continuously from 1 October 1999 until 30 September 2000 although the station was only calibrated from 1 April 2000 until 15 September 2000. Data is good for the period of calibration except for data between about 29 July 2000 and 2 August 2000. River silt accumulated around the end of the probe and reduced the circulation near the sensors. Consequently, dissolved gas readings were lower during this period. By early June, the silting had begun to prevent adequate fresh sample from reaching the instruments. This had a dramatic impact on data quality so, in mid-June the decision was made to deploy the instruments outside the protective deployment pipe on a full-time basis. This event occurred at the same time that the new barometer was being incorporated in the calibration procedures. The large delta TDG and temperature values can be attributed to both these events.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0729 2100 - 0802 1300	TDG	<90	95 - 120

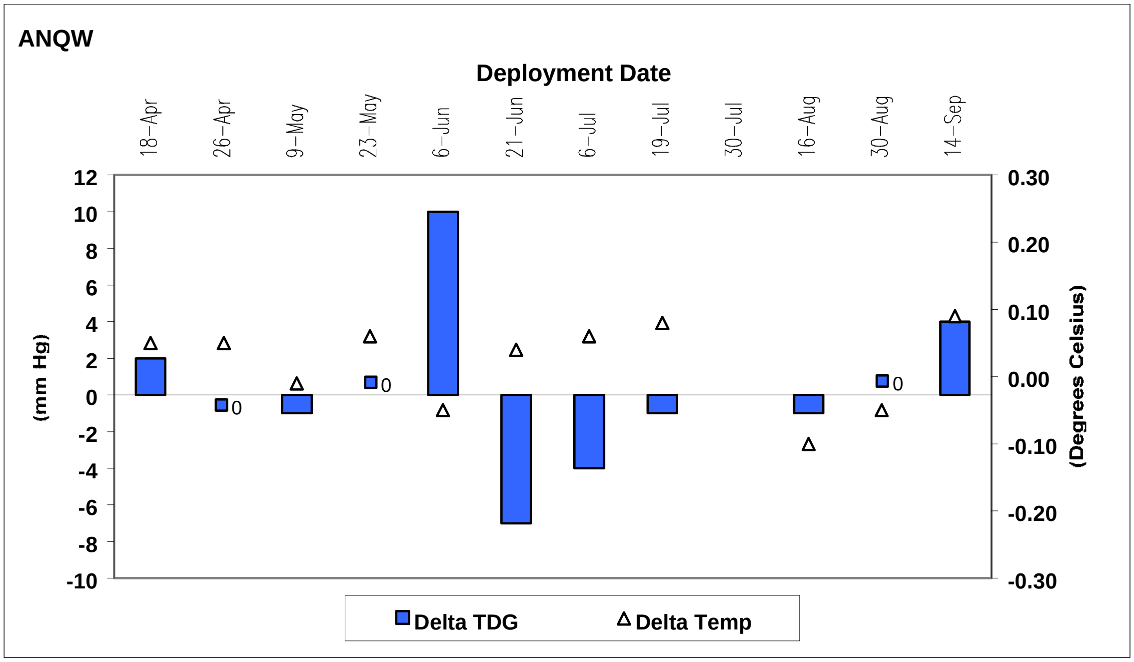

Figure 2. Control Chart for Station ANQW.

b. Station DWQI - North Fork of the Clearwater River Below Dworshak Dam, Idaho.

Dworshak Dam's tailwater station is on the left bank at RM 0.5. It is approximately 7,900 feet downstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000. Several short outages occurred. On 31 May 2000, the station was down while the modem was serviced. Readings show gaps and abnormally high readings for that period. From 23 June 2000 until 5 July 2000, the station went through a period of sporadic outages lasting 4 to 12 hours. Cables were systematically replaced until the station resumed operation. The readings that were transmitted seem to be in the normal range for this station.

The higher delta TDG values in June are related to the implementation of a new barometric pressure standard that is used to calibrate the instruments and does not reflect a decrease in the ability of the station to provide fresh sample to the instruments. Notice the increased precision for both TDG and temperature after the implementation of new standards and calibration procedures.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0531 1000 - 0531 2000	TDG	>150	95 - 120
0531 1000 - 0531 2000	BP	>700	550 - 700
0531 1000 - 0531 2000	WT	>100	40 - 70
0623 1800 - 0705 1300	TDG	0	95 - 120
0623 1800 - 0705 1300	WT	0	40 - 70

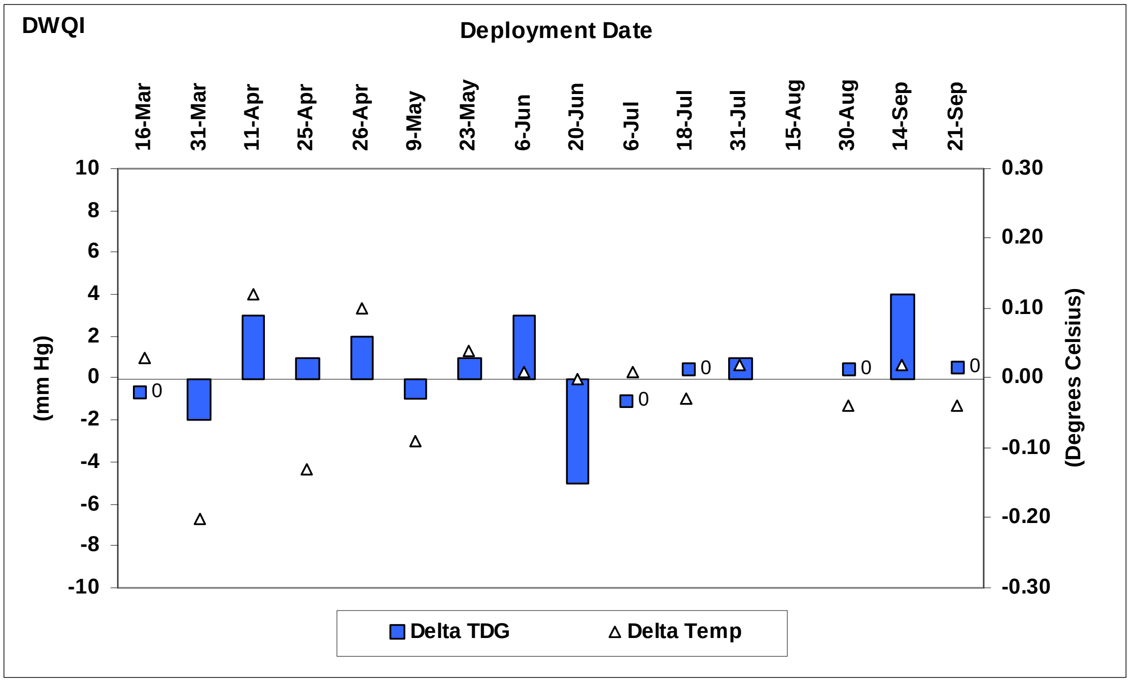

Figure 3. Control Chart for Station DWQI.

c. Station LEWI - Clearwater River at Lewiston, Idaho.

The Lewiston station is on the right side of the river near the city's water intake at RM 5.1. The station operated continuously from 1 April 2000 until 30 August 2000. The station would normally be active until 15 September 2000 but low flows made monitoring impossible. In addition, the station experienced several short outages of 1 to 3 hours.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0606 1500 - 0606 1600	TDG	No Data	95 - 120
0624 2200 - 0624 2400	TDG	>125	95 - 120
0624 2200 - 0624 2400	WT	0	40 - 70
0624 2200 - 0624 2400	BP	0	750 - 800
0625 2300 - 0625 2400	WT	0	40 - 70
0625 2300 - 0625 2400	BP	0	750 - 800

d. Station PEKI - Clearwater River at Peck, Idaho.

The Peck station is on the left side of the Clearwater River at RM 37.4. The station operated continuously from 1 April 2000 until 2 September 2000. Like the station at Lewiston, Peck would have been active until 15 September but low flows prevented access to the water.

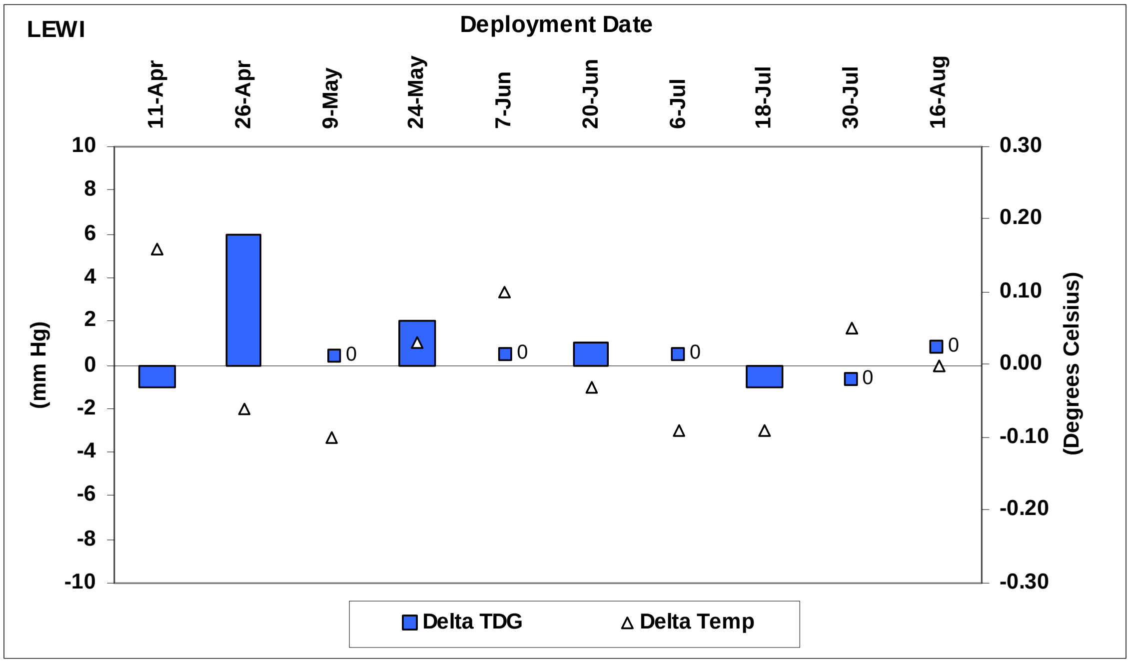

Figure 4. Control Chart for Station LEWI.

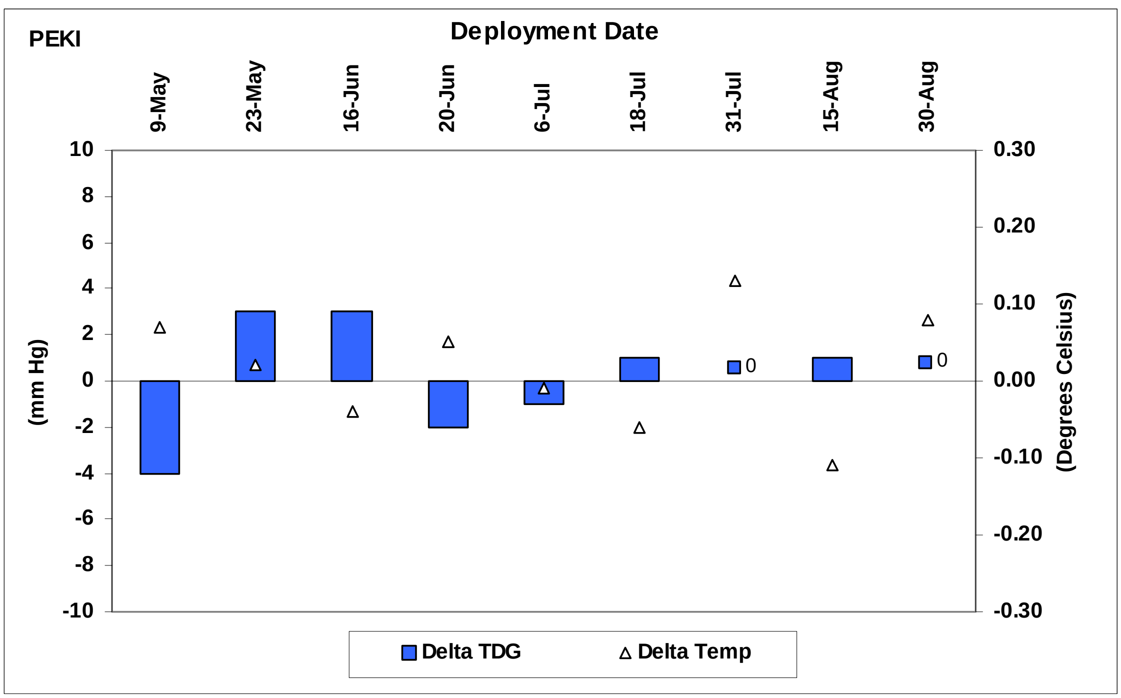

Figure 5. Control Chart for Station PEKI.

e. Station LWG - Snake River at Forebay at Lower Granite Dam, Washington.

This station is located at the end of the navigation lock guide wall, about 630 feet upstream of the dam and right of the middle of the river. The station operated continuously from 1 October 1999 until 30 September 2000 with no outages.

The data quality at this station reflects changes that were made to the standard operating procedures in May 2000 and the incorporation of the new standards in June to July 2000. After each of these changes, the station performance returned to normal. The larger delta TDG in late August marks the beginning of an increasing trend that continued on into the next fiscal year. This increase in delta TDG is likely related to poor circulation in the forebay pool as described in previous sections.

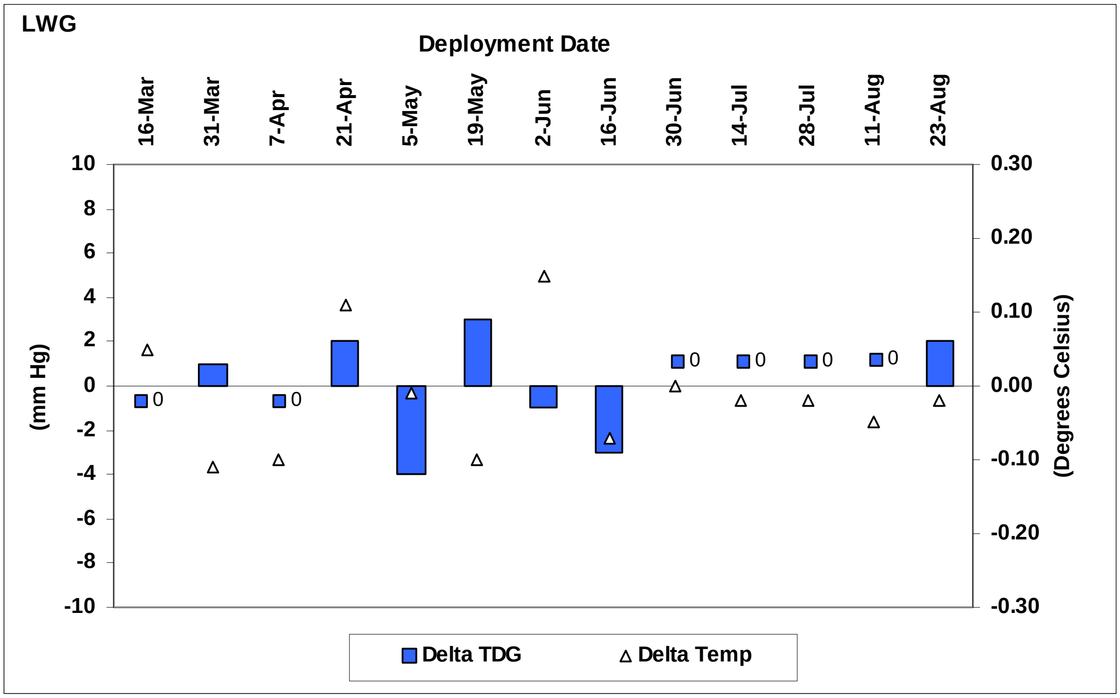

Figure 6. Control Chart for Station LWG.

f. Station LGNW - Snake River Below Lower Granite Dam, Washington.

Lower Granite's tailwater station is on the right bank at RM 106.8, approximately 3,500 feet downstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 with no unexpected outages.

This station provided high quality data throughout the entire year. The delta values in June 2000 can be attributed to the new standards used for instrument calibration. They do not reflect station performance.

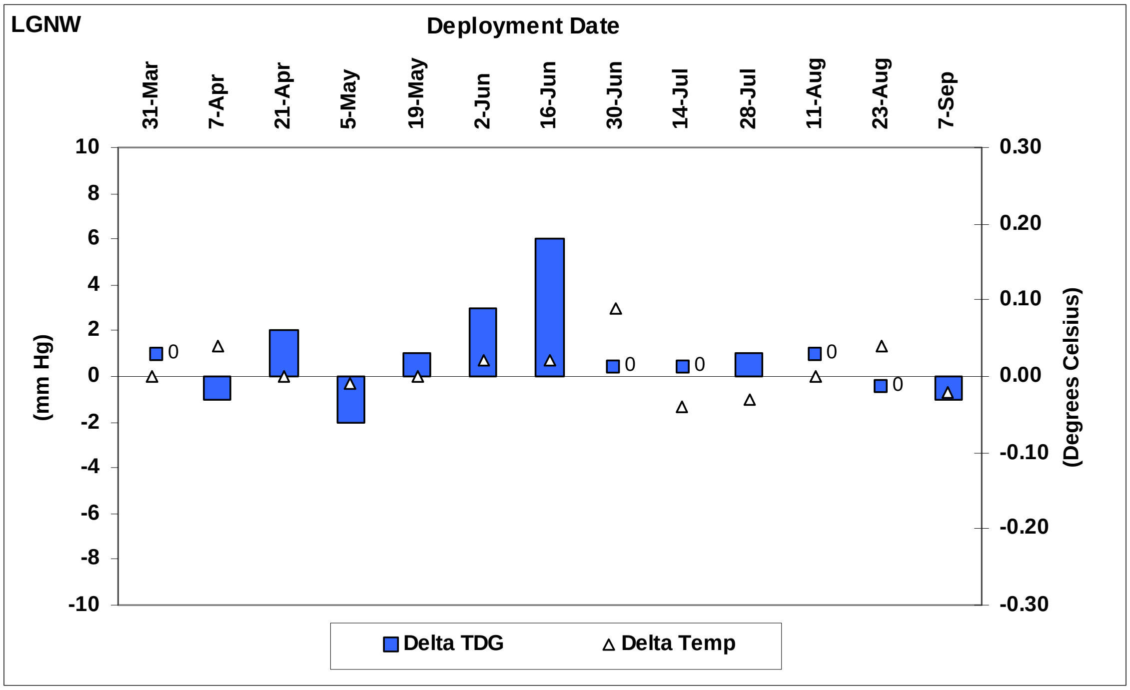

Figure 7. Control Chart for Station LGNW.

g. Station LGS - Snake River at Forebay at Little Goose Dam, Washington.

This station is on the face of the dam at about mid-river. The station operated continuously from 1 April 2000 until 15 September 2000 with no extended outages.

This station provided high quality data throughout the entire year. The delta values in June 2000 can be attributed to the new standards used for instrument calibration. They do not reflect station performance.

h. Station LGSW - Snake River Below Little Goose Dam, Washington.

This tailwater station is on the right bank at RM 69.5, about 3,900 feet downstream of the dam. The station operated continuously from 1 April 2000 until 15 September 2000 with two short outages. Three hours of data were lost on 26 June 2000 due to unknown causes and faulty servicing on 7 September 2000 caused a break in data that lasted until the next day. Again, slow posting of data caused the problem to go unnoticed during the afternoon of 7 September 2000.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0626 0600 - 0626 0900	TDGP	<500	750 - 800
0626 0600 - 0626 0900	WT	No Data	40 - 70
0907 1600 - 0908 1200	TDG	0	95 - 120
0907 1600 - 0908 1200	WT	0	40 - 70

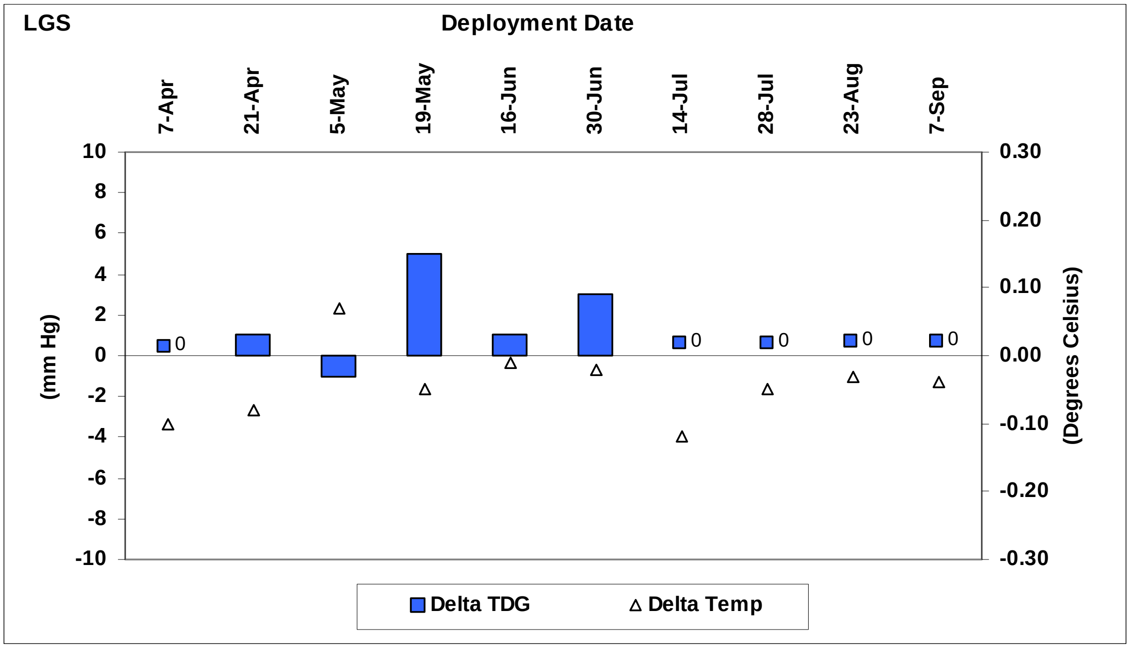

Figure 8. Control Chart for Station LGS.

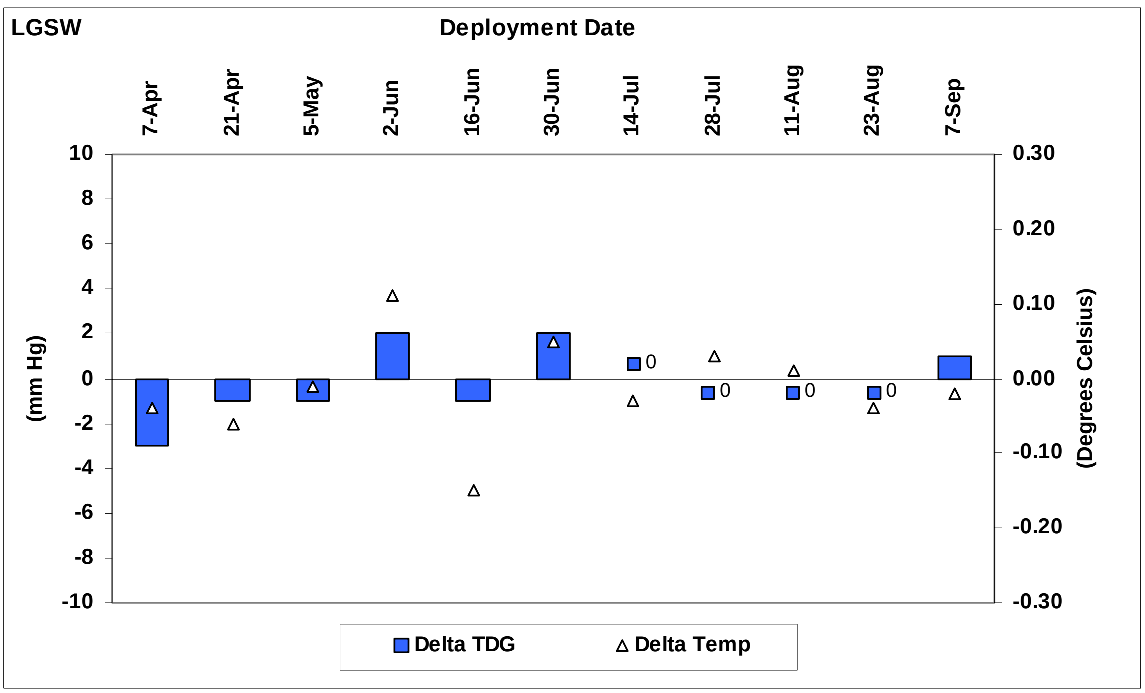

Figure 9. Control Chart for Station LGSW.

i. Station LMN - Snake River at Forebay at Lower Monumental Dam, Washington.

This station is on the face of the dam at about mid-river. The station operated continuously from 1 April 2000 until 15 September 2000 with no extended outages.

The positive impact that the new calibration standards had on station performance is very evident at this station. In late June, after the new barometer and thermometer were incorporated into procedures, the TDG and temperature data improved dramatically.

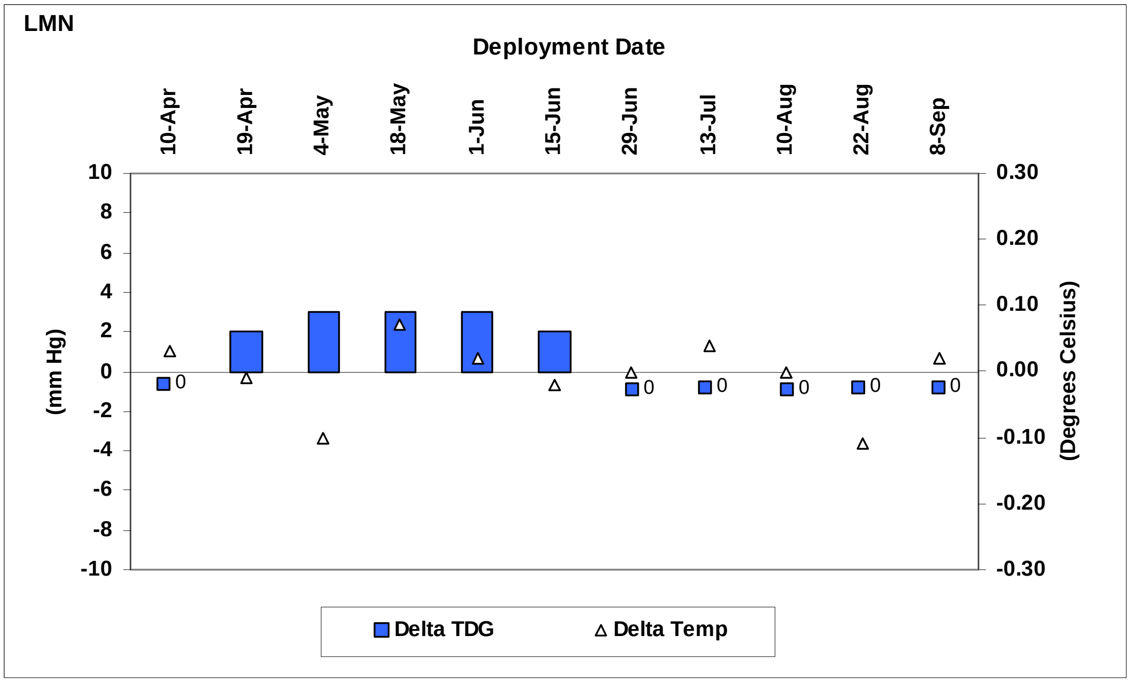

Figure 10. Control Chart for Station LMN.

j. Station LMNW - Snake River Below Lower Monumental Dam, Washington.

This station is on the left bank at RM 40.8, approximately 4,320 feet downstream of Lower Monumental dam. The station operated continuously from 1 April 2000 until 15 September 2000 with a short outage on 18 May 2000 from 1300 until 19 May 2000 at 1300. Routine service resulted in a bad electrical connection. Slow posting of data prevented the problem from being discovered until the next day. The station went partially down again on 25 August 2000 at 1800 but self-started again at 0400 on 27 August 2000. No service was required. The cause of failure was never determined.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0518 1300 - 0519 1200	TDG	0	95 - 120
0518 1300 - 0519 1200	WT	32 (° C)	40 - 70
0825 1800 - 0827 0300	TDG	0	95 - 120

The data quality at this station reflects changes that were made to the standard operating procedures in May 2000 and the incorporation of the new standards in June to July 2000. After each of these changes, the station performance returned to normal.

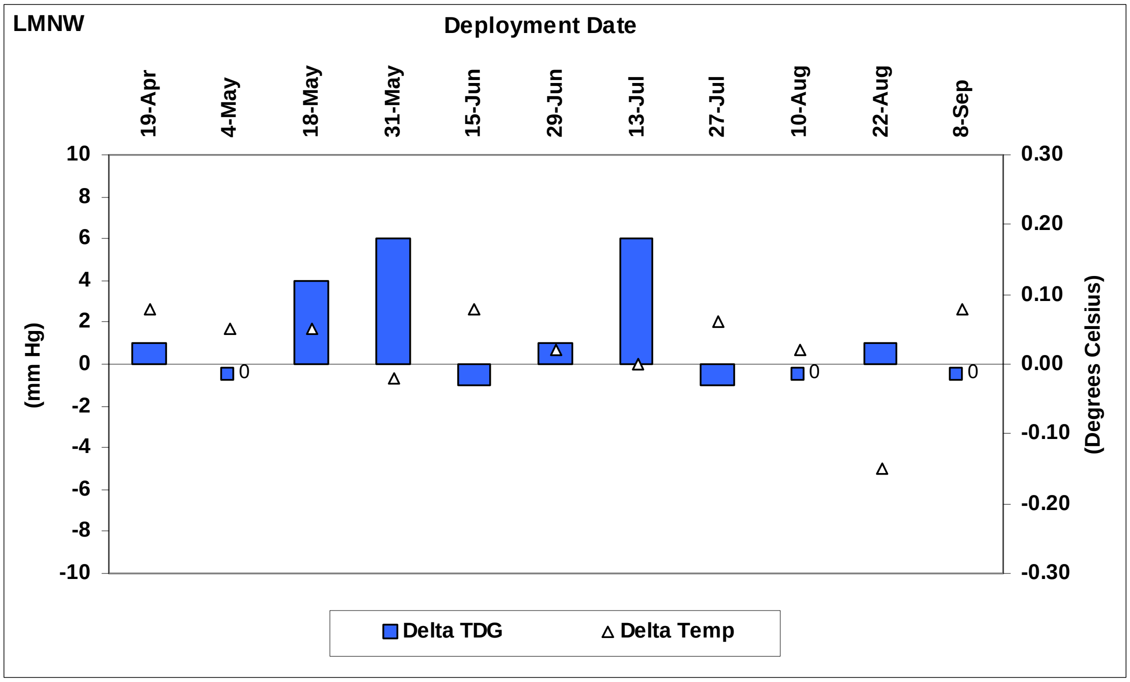

Figure 11. Control Chart for Station LMNW.

k. Station IHR - Snake River at Forebay at Ice Harbor Dam, Washington.

The Ice Harbor station is mounted on the upstream face of the dam approximately at mid-river. The station operated continuously from 1 October 1999 until 30 September 2000 with no extended outages.

The station performed very well throughout the spring and summer. As the fish passage season came to an end in early September, the reduction in spill levels caused the circulation in the pool to diminish and likely caused stagnation in and around the deployment pipe that resulted in larger delta values. The small circulators on the instruments could not adequately mix the stagnant water, causing each instrument to read the water quality in its own microenvironment. This scenario is common among the forebay stations and is consistent with data from other years. There are improvements planned to address this issue. One solution may be to install small circulating pumps inside the pipe to purge the pipe several times an hour to ensure that an adequate volume of fresh sample can reach the instruments.

l. Station IDSW - Snake River Below Ice Harbor Dam, Washington.

The Ice Harbor tailwater station is on the right bank at RM 6.8 and is 15,400 feet downstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 but had a problem on 12 July 2000. The electrical cable was vandalized and the station stopped reporting at 0700 12 July 2000. A technician serviced the unit at 1100 on 13 July 2000. The station completed one 4-hour cycle and failed again due to a fault in the replacement cable. A second servicing brought the station back on-line on 14 July 2000.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0712 1700 - 0714 1200	TDG	0	95 - 120
0712 1700 - 0714 1200	WT	32 (° C)	40 – 70

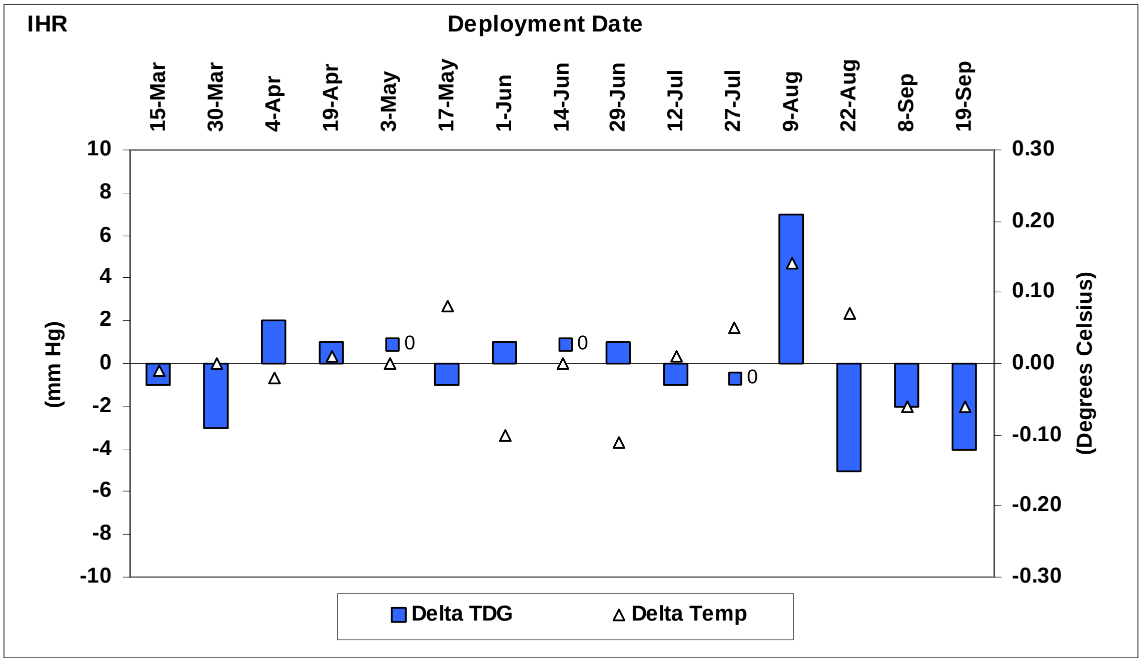

Figure 12. Control Chart for Station IHR.

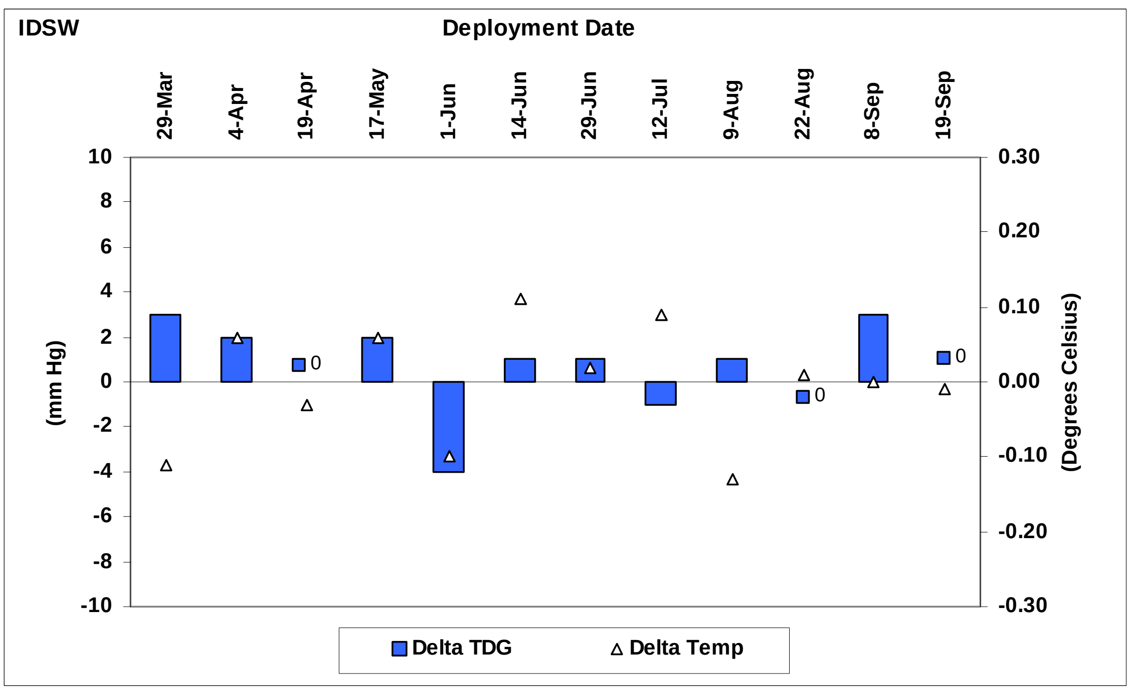

Figure 13. Control Chart for Station IDSW.

m. Station PAQW - Columbia River at Pasco, Washington.

The Pasco station is on the left side of the river at RM 392.0. The station operated continuously from 1 April 2000 until 15 September 2000. An outage occurred on 22 August 2000 at 0700 following routine station service. Due to slow reporting, the problem wasn't discovered until 23 August 2000 and was quickly fixed. The station was non-reporting from 0700 22 August 2000 until 1100 23 August 2000. The cause is unknown.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0822 0700 - 0823 1100	TDG	<50	95 – 120

The only two delta TDG values worth noting are both related to instrument performance and not station performance. The 4 April 2000 value is related to modifications in the standard operating procedures for calibrating the instruments. The 28 June 2000 value is related to the incorporation of the new barometer standard into the system.

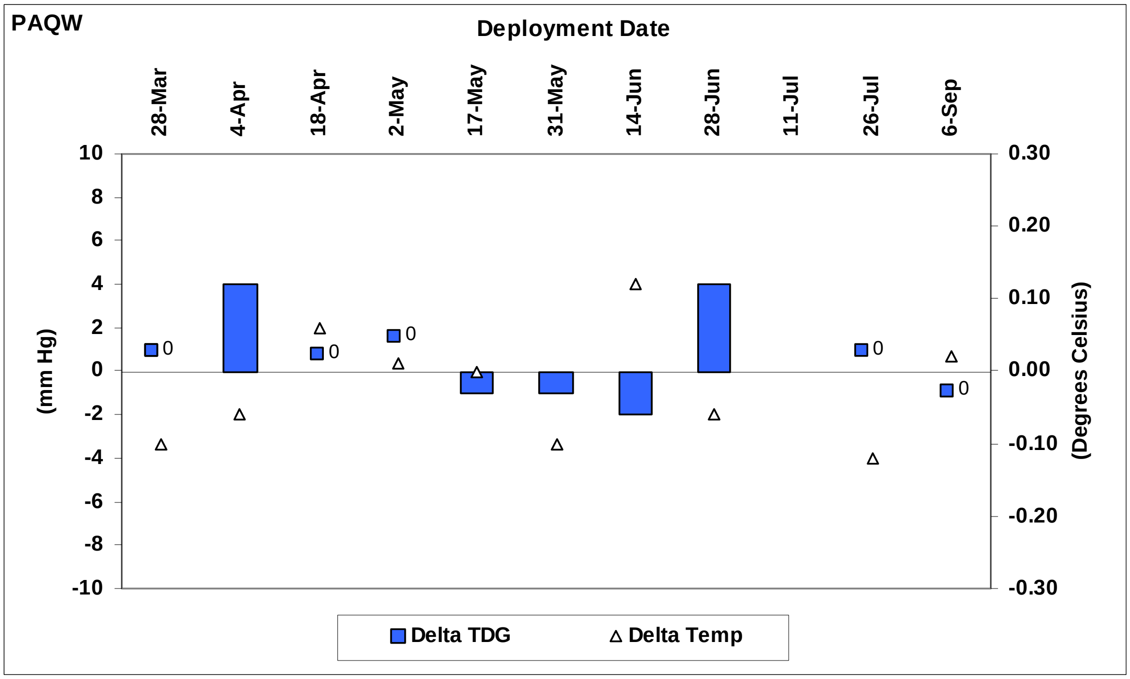

Figure 14. Control Chart for Station PAQW.

n. Station MCQO - Columbia River Forebay at McNary Dam, Oregon.

The McNary forebay station on the Oregon side is located on the upstream face of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 with no outages.

New standard operating procedures in May, new standards in June-July, and late-season forebay circulation dynamics all overlap to account for the sporadic delta values at this station. The underlying station performance is quite good and the station performance data for the following year should improve based on the changes made this season.

o. Station MCQW - Columbia River Forebay at McNary Dam, Washington.

The McNary forebay station on the Washington side is mounted on the upstream end of the Washington shore fish ladder, about 295 feet upstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 with no problems.

Station MCQW experienced the same improvements that occurred at MCQO; however, this station did not produce such large delta values late in the fish passage season. This is likely due to the fact that this station is located on the Washington side of the river and is mostly influenced by the Columbia River discharge, which is much greater than the Snake River discharge that influences the Oregon side of the pool. This station is also located approximately 100 feet from the dam, removing it from the stagnant water trapped between the closed spillway structures.

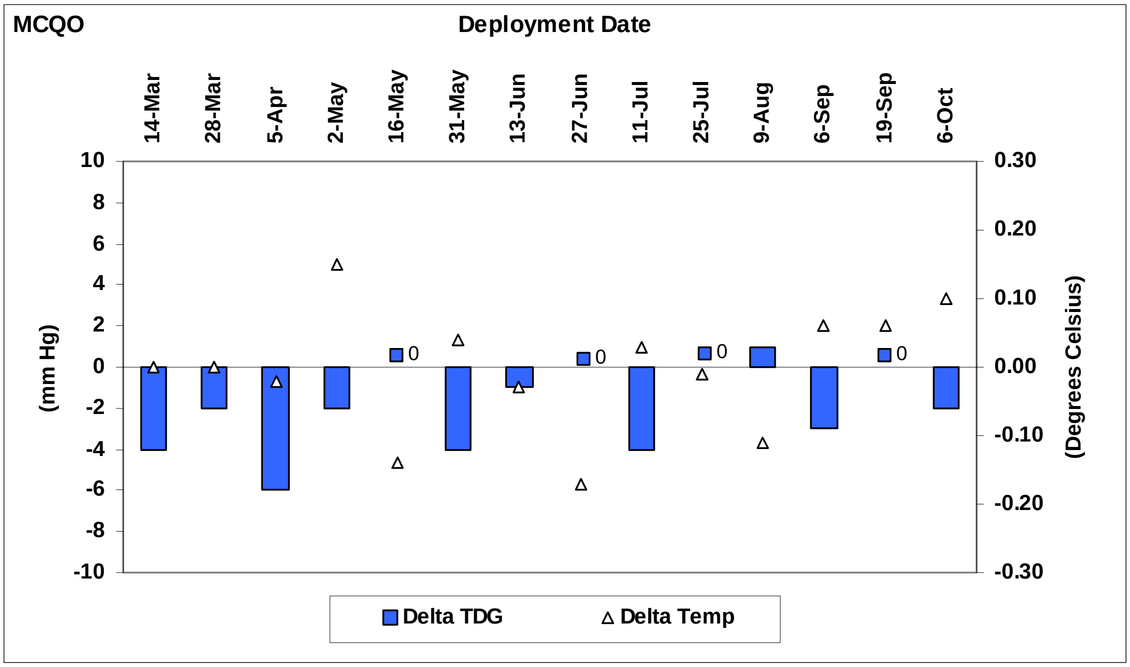

Figure 15. Control Chart for Station MCQO.

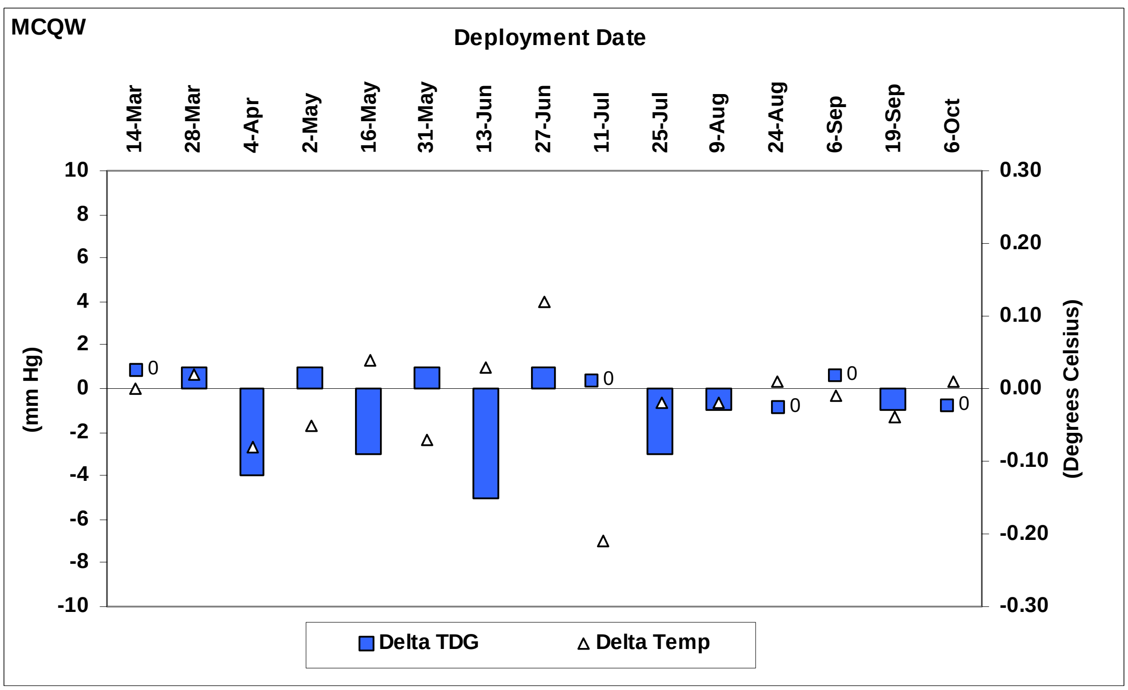

Figure 16. Control Chart for Station MCQW.

p. Station MCPW - Columbia River Below McNary Dam, Washington.

The McNary tailwater station is located on the right bank at RM 290.6, which is approximately 7,300 feet downstream of the dam. The station operated continuously from 1 October 1999 until 31 September 2000 with two short outages. One was at 0900 on 27 April 2000. Water temperature and dissolved gas sensors recorded high readings for 3 hours followed by 18 hours of low water temperature readings. The second outage was at 1000 on 16 June 2000 following battery replacement. The succeeding four reports failed to transmit.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0427 0900 - 0427 1200	TDG	>120	95 - 120
0427 0900 - 0428 0400	WT	V>50, V<40	40 - 70
0616 1000 - 0616 1300	TDG	No data	95 - 120
0616 1000 - 0616 1300	WT	No data	40 - 70

Incorporation of the new barometer into the standard operating procedures improved the station performance data by increasing the precision of the instruments.

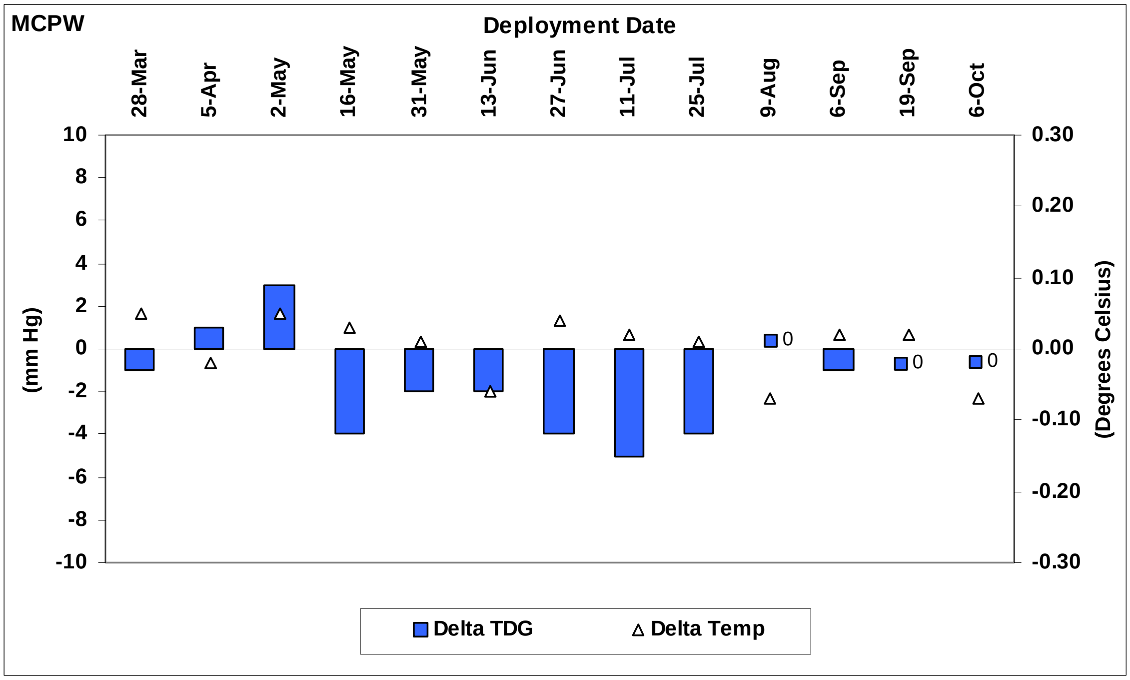

Figure 17. Control Chart for Station MCPW.

Individual Water Quality Sonde Performance.

The individual sondes are, in many ways, the major components of the system and require the highest level of maintenance and QA. Based on historic data, CENWW decided that performing calibration procedures in a laboratory produced the most precise and reproducible results. It is difficult to attempt calibration in the field under dynamic and sometimes adverse conditions. Furthermore, the mercury NBS standards and highly sensitive pressure calibrator devices are dangerous and costly to transport in the field. Subsequent paragraphs describe the individual sonde performance and history. This information was used to make in-season determinations of sonde mission capability and fleet management.

The results of the statistical analyses performed on the QA/QC data for the entire inventory of instruments indicate that the instruments performed within the upper and lower QC limits and the DQO's for most of the time. Data recorded by faulty or failing sensors were not used in the overall performance evaluation.

The DQO for TDG calibration delta values is 2 mm Hg. The results of the cumulative analyses indicate that the mean delta value for the Base TDG calibration parameter was 0.13 mm Hg with a standard deviation of ±1.07. The mean delta value for the Pressurized TDG calibration parameter was 0.25 with a standard deviation of ±1.11. Both parameters are well below the DQO's for the year.

The DQO for temperature is 0.10° C. The results of the cumulative analyses indicate that the cumulative temperature variance calculated for all of the instruments resulted in a mean delta value of -0.04° C with a standard deviation of ±0.07° C. This is well within the manufacturer's specifications and the district's DQO's. The thermisters consistently read below the standard temperature by approximately 0.05° C. These sensors are factory calibrated and, therefore, this is likely an artifact of production. The precision of the thermisters is well within the manufacturer's specifications.

Month	Mean Delta Base TDG*	Stdev Base TDG	Mean Delta Pres TDG*	Stdev Pres TDG	Mean Delta Temp**	Stdev Temp
October	nd	nd	Nd	nd	nd	Nd
November	nd	nd	Nd	nd	nd	Nd
December	nd	nd	Nd	nd	nd	Nd
January	nd	nd	Nd	nd	nd	Nd
February	nd	nd	Nd	nd	nd	Nd
March	-0.19	1.05	0.31	0.87	nd	Nd
April	0.36	0.95	0.71	1.08	-0.10	0.06
May	0.29	1.45	0.45	1.64	-0.04	0.06
June	0.26	1.07	0.14	1.12	-0.05	0.06
July	-0.09	1.09	0.03	0.89	-0.02	0.06
August	0.08	0.84	0.19	0.69	-0.04	0.09
September	-0.05	0.23	-0.16	0.37	-0.04	0.08
Cumulative	0.13	1.07	0.25	1.11	-0.04	0.07
nd = No Data (statistical analyses began in March 2000)						
*** - results are reported in (mm Hg)**						
**** results are reported in (Degrees Celsius)**						

Table 3. Monthly and Cumulative Mean Delta and Standard Deviation Calculations for Entire Inventory of TDG and Temperature Sensors.

a. Sonde #01.

This unit was deployed and actively used from the beginning to the end of last year's field season. It posed no real problems in calibration and was within 2 mm Hg of the NBS pressure standard or the QA/QC sonde throughout this season. The temperature was consistently 0.1° C lower than the calibrated QC or NBS standard. This was still within the manufacturer's warranty and specifications. This also met CENWW's control limits.

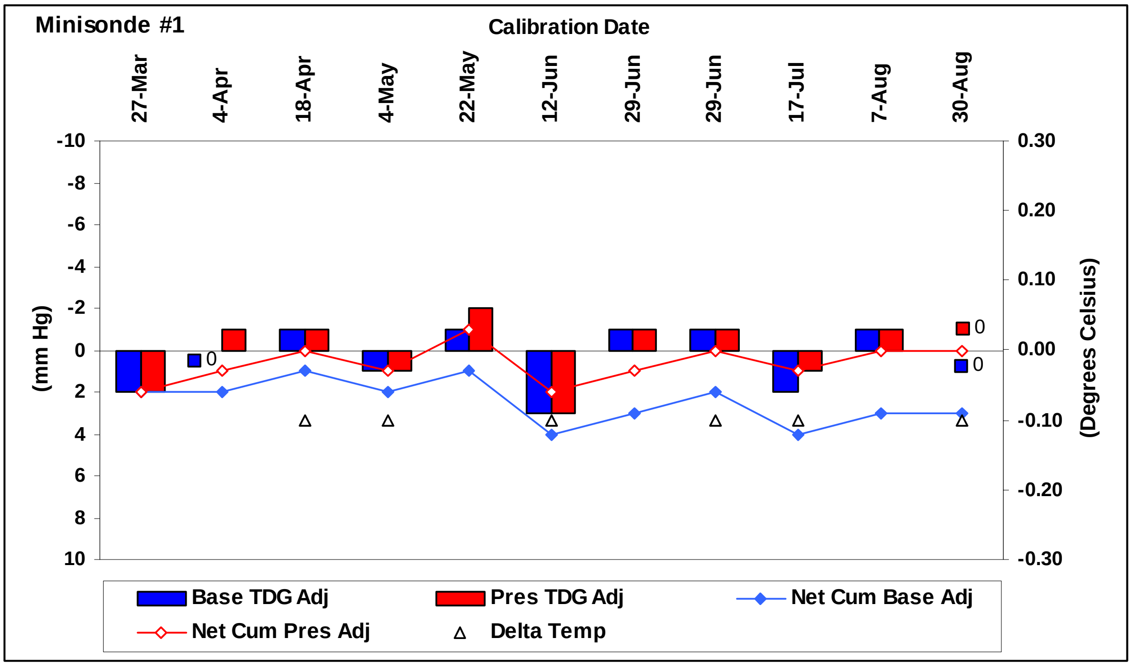

Figure18. Control Chart for Hydrolab Minisonde Serial Number 32431 (#01).

b. Sonde #02.

This unit was into the manufacturer for repairs and was not placed into general service until May. It posed no real problems in calibration and was within 2 mm Hg of the NBS pressure standard or the QA/QC sonde throughout this season. The temperature was consistently 0.1° C lower than the calibrated QC or NBS standard. This was still within the manufacturer's warranty and specifications. This also met CENWW's control limits.

c. Sonde #03.

This unit was in service for most of the season. In late June and early July, there were some pressure calibration problems. After a factory calibration and service of the pressure transducer, it gave near perfect performance in August. It was on the average within 2 mm Hg of the NBS pressure standard or the QA/QC sonde throughout this season. The temperature was consistently 0.1 C° lower than the calibrated QC or NBS standard. This was still within the manufacturer's warranty and specifications. This also met CENWW's control limits.

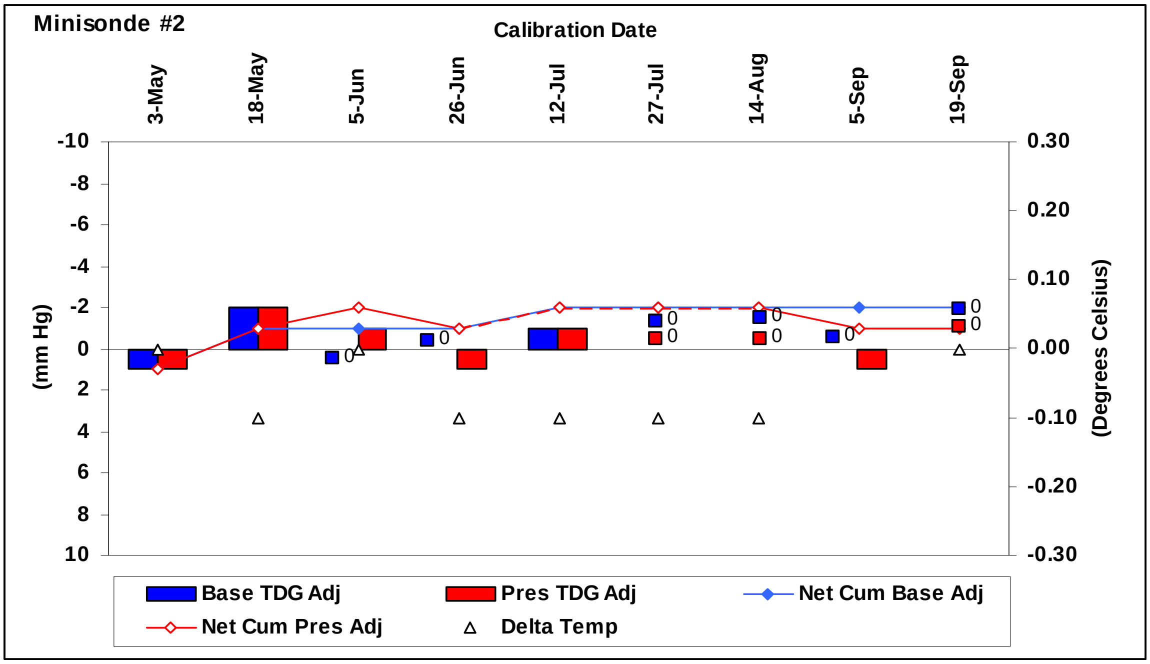

Figure 19. Control Chart for Hydrolab Minisonde Serial Number 32466 (#02).

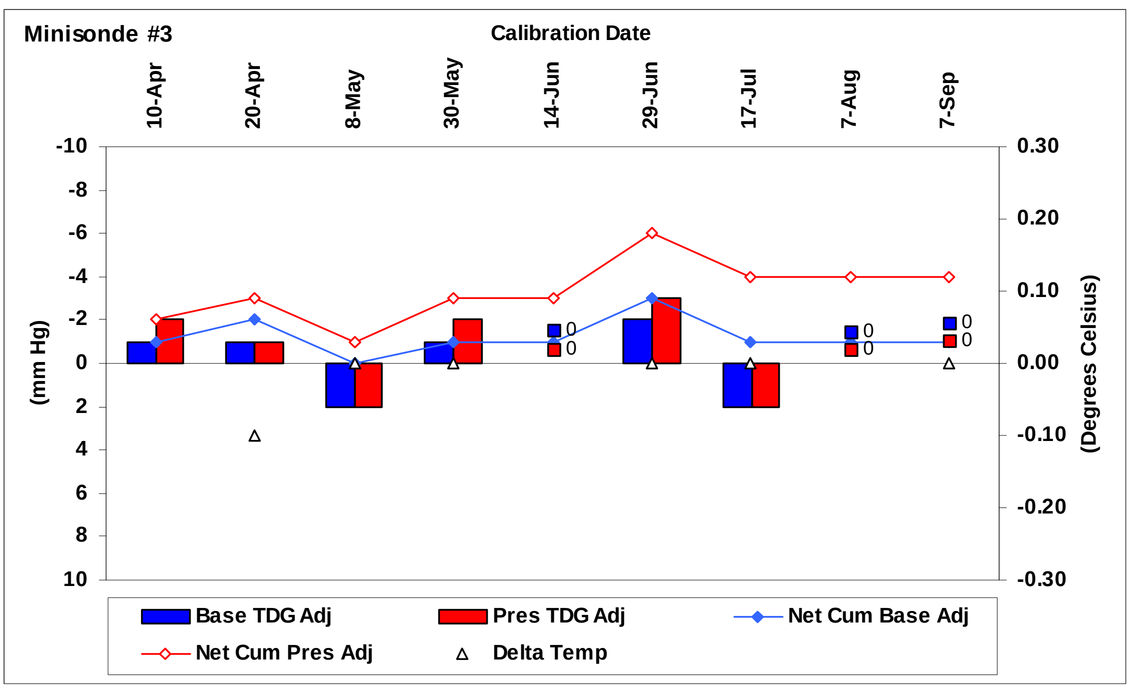

Figure 20. Control Chart for Hydrolab Minisonde Serial Number 32441 (#03).

d. Sonde #04.

This unit is operational but was retained at the CENWW lab for tests and evaluations or as an emergency backup in case a repair was needed on weekends. This unit was used as a static test unit in the hyperbaric chamber experiments. No comparable QA/QC station performance data was collected for this unit in water year 2000.

e. Sonde #05.

Unit #05 was utilized regularly during the season and provided excellent results. The unit did prove a little cantankerous to calibrate (it is part of the first batch of units procured) but once calibrated it exceeded manufacturer's specifications and our QA expectations. The temperature was almost always exactly the same as the NBS standard and the TDG averaged approximately within 1 mm Hg of accuracy. For all practical purposes this met all significant numbers and further QC would be a magnitude of order greater requiring new equipment and increased QA/QC. This unit is considered to be one of the best since further precision and accuracy beyond what this unit produces is not possible. This unit exceeds manufacturer's specifications and current QA/QC standards.

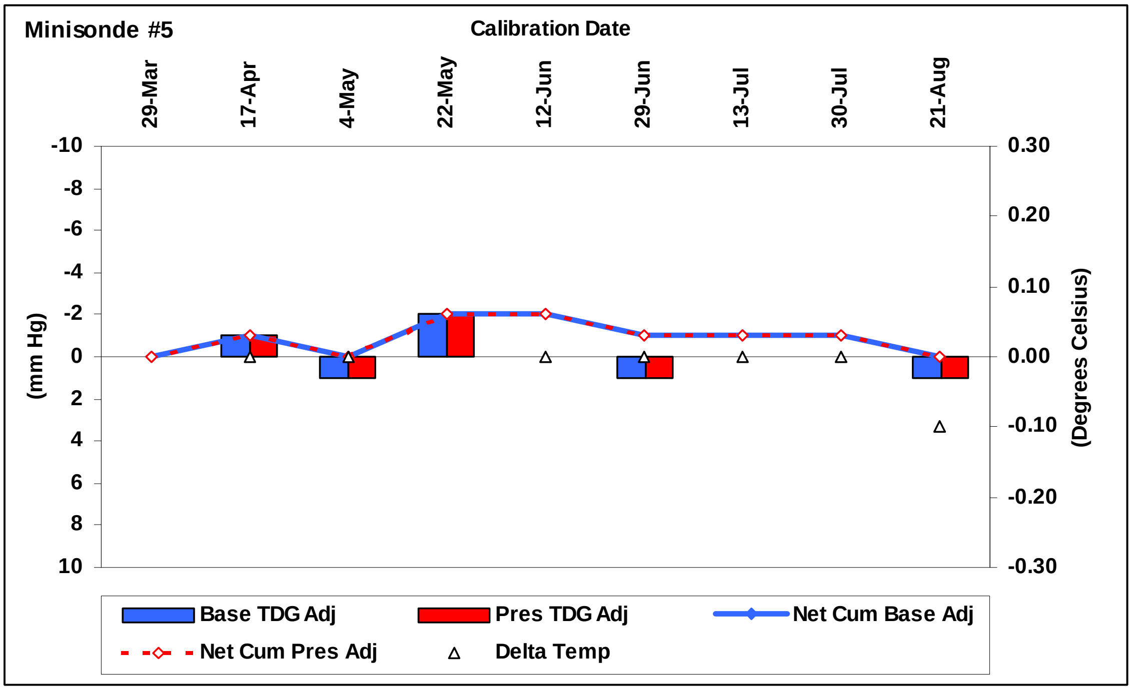

Figure 21. Control Chart for Hydrolab Minisonde Serial Number 32444 (#05).

f. Sonde #06.

This unit was used in April and May. In May, this unit became non-mission capable and remained in this state for the remainder of the year because, although it would calibrate, the data was not considered to be reliable when tested over a week's period in the lab. The QA officer decided to restrict its deployment until it received a complete overhaul at the factory. This unit is currently in a non-mission-capable status.

g. Sonde #07.

This unit started service in early March and was providing quality service until May. After two deployments, it was determined this unit was not meeting QC. The unit calibrated correctly but did not provide quality field service. The instrument had its software and drivers erased and updated with the latest Hydrolab firmware. From then on, it became one of the best performing units and maintained accuracy for months on end.

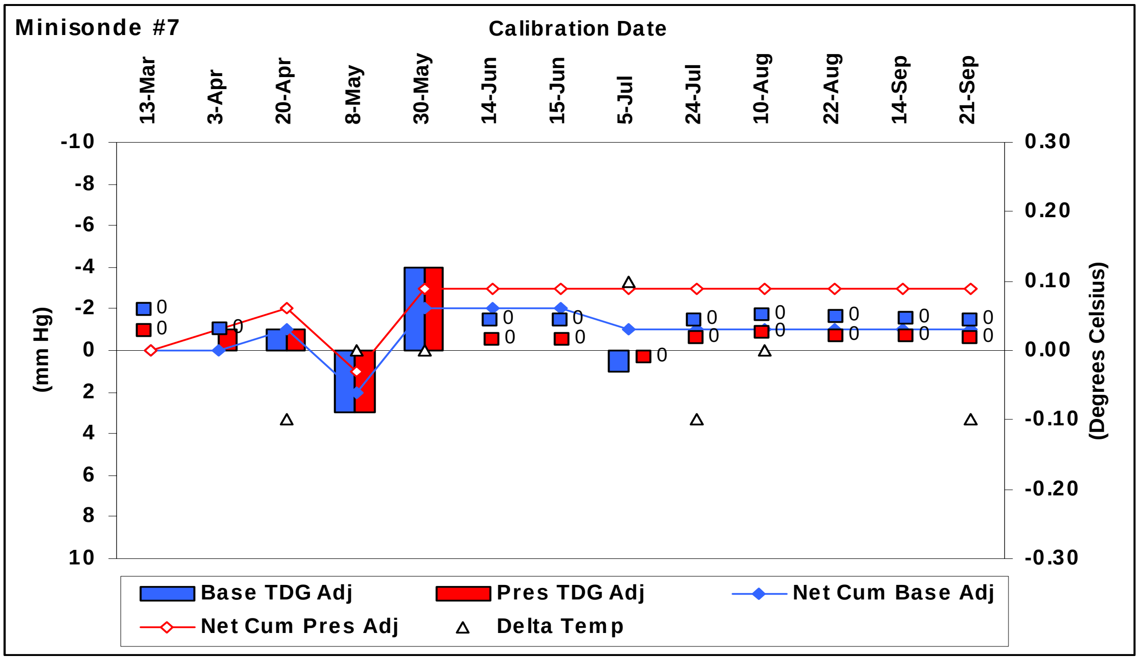

Figure 22. Control Chart for Hydrolab Minisonde Serial Number 32427 (#07).

h. Sonde #08.

This unit was deployed continuously during the field season and was utilized frequently as a QA/QC sonde. With the exception of two data points, this unit matched the standards. For all practical purposes this met all significant numbers and further QC would be a magnitude of order greater requiring new equipment and increased QA/QC. This unit is considered to be one of the best since further precision and accuracy beyond what this unit produces is not possible. This unit exceeds manufacturer's specifications and current QA/QC standards.

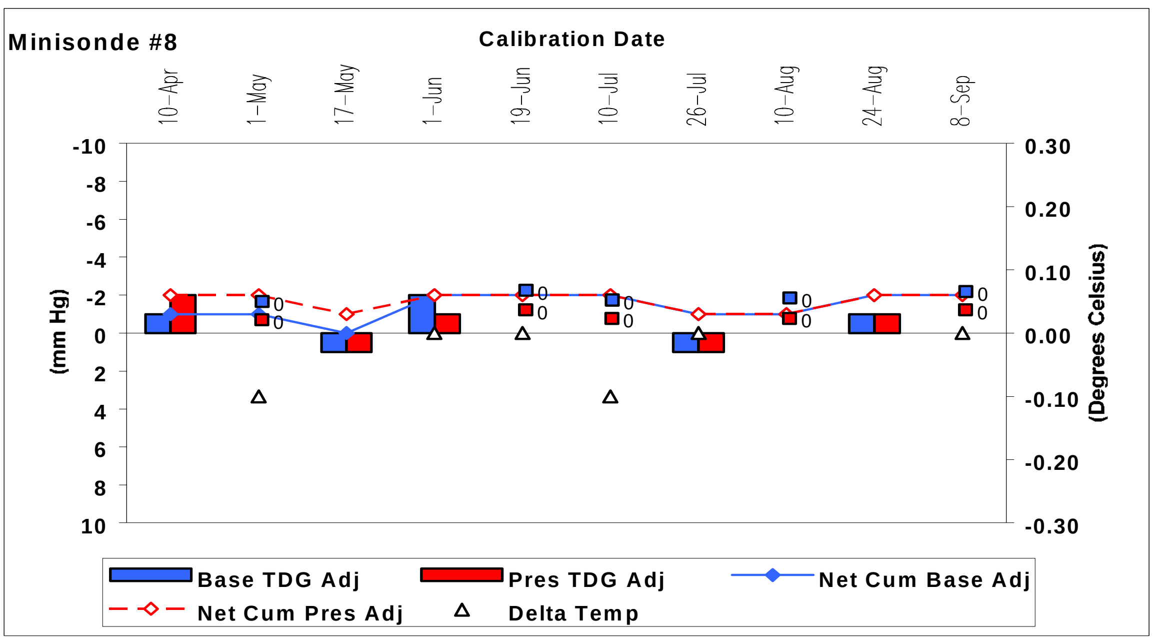

Figure 23. Control Chart for Hydrolab Minisonde Serial Number 32432 (# 08).

i. Sonde #09.

This unit was utilized for the first 2 months of this season. In May, the instrument received physical damage and was not repaired until August. The unit was utilized in early water year 2001 with success.

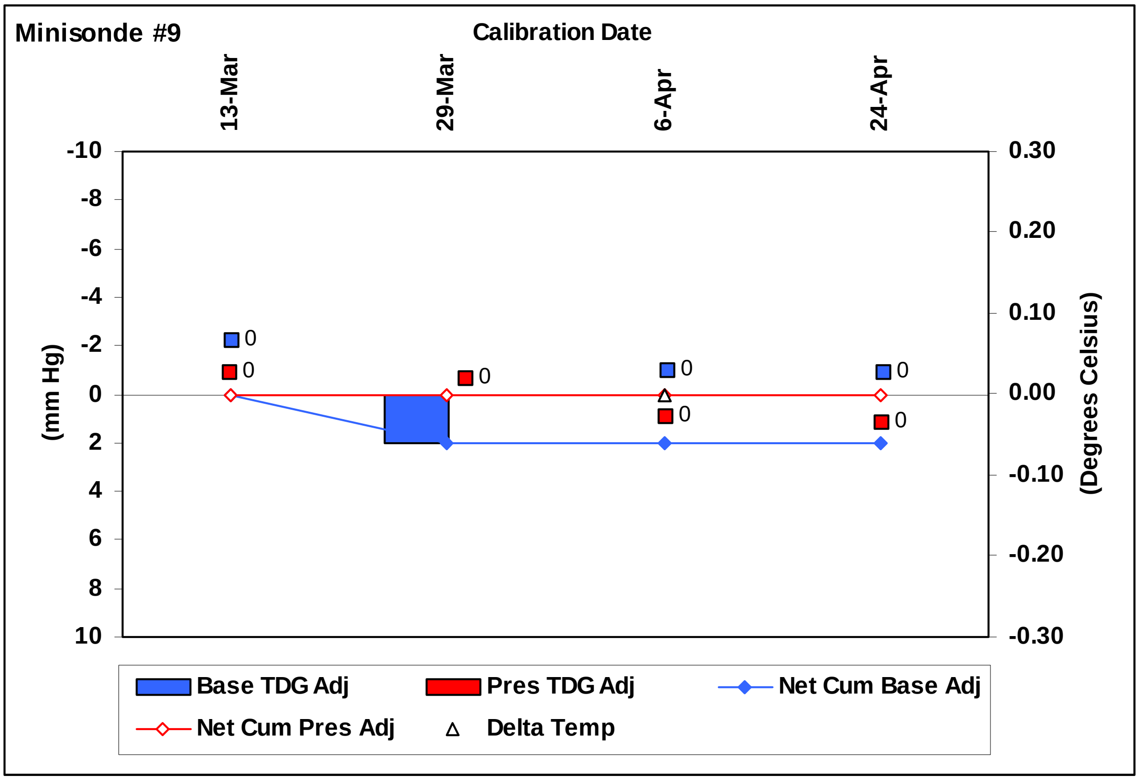

Figure 24. Control Chart for Hydrolab Minisonde Serial Number 32420 (#09).

j. Sonde #10.

This unit was in service a majority of the time during this year's season. The temperature was nearly identical to the NBS standard. The TDG sensor did fluctuate throughout the period of service but was within the QA/QC and the manufacturer's specifications. In July and August, the instrument tolerances were at the loosest. However, after thorough lab tests and evaluation no problems were detected and it performed perfectly in September.

k. Sonde #11.

This instrument was used for most of the season. There was a bit more flux in the temperature sensor as compared to some of the better instruments. This instrument did perform within the manufacturer's specifications and met CENWW's QC.

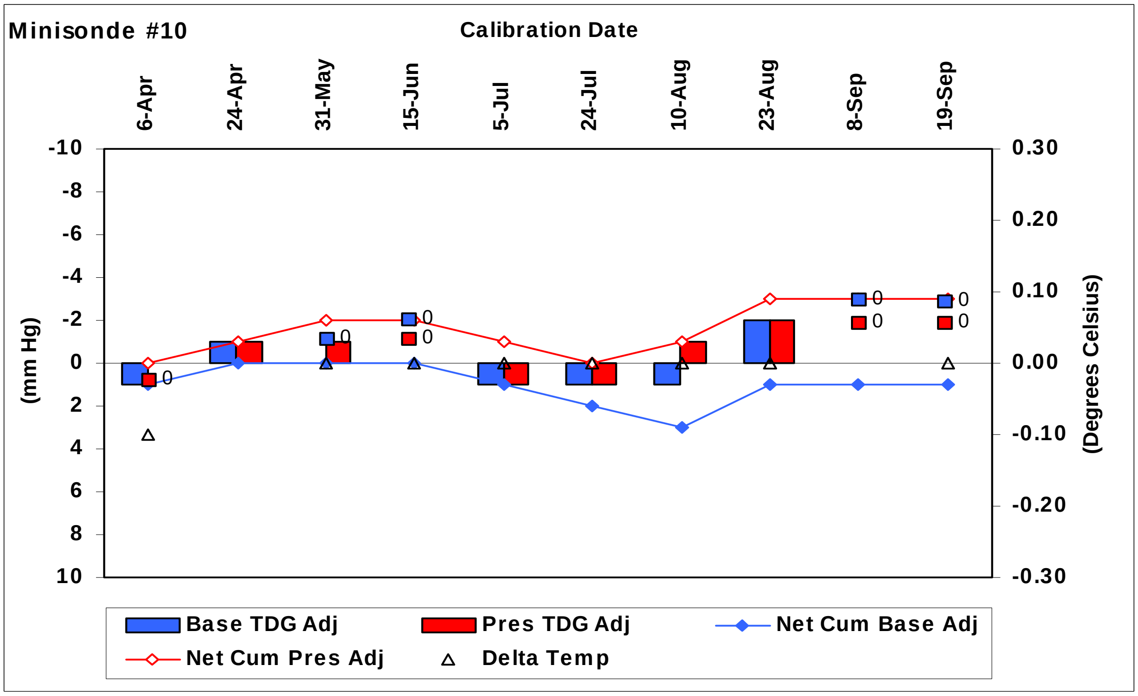

Figure 25. Control Chart for Hydrolab Minisonde Serial Number 32428 (#10).

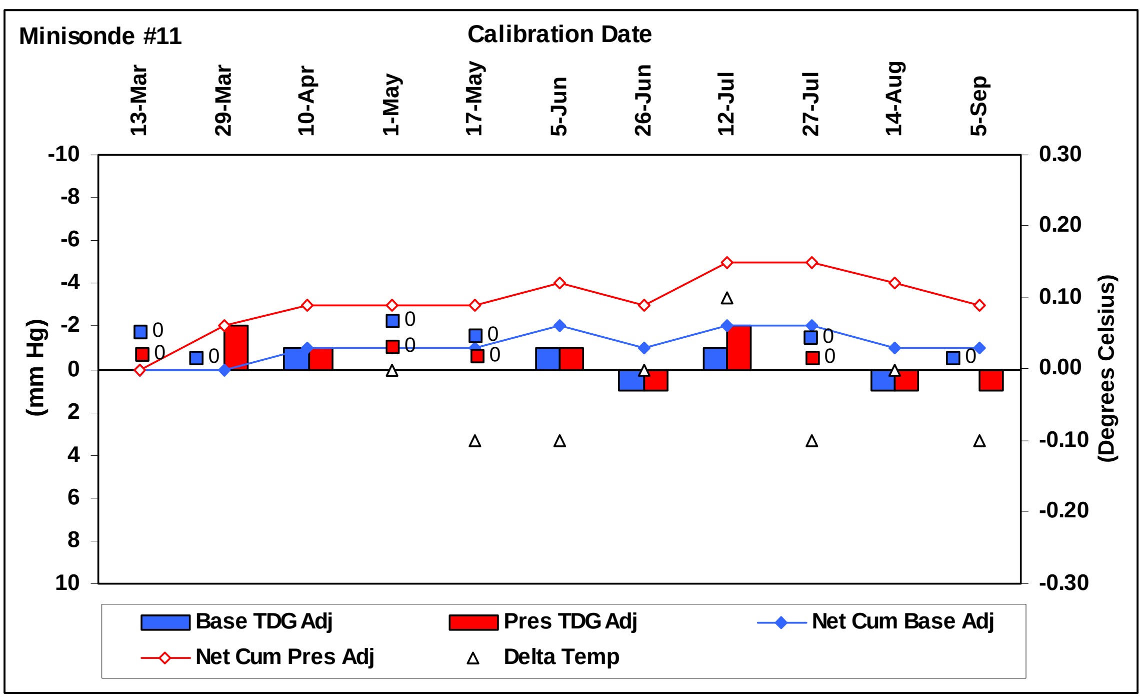

Figure 26. Control Chart for Hydrolab Minisonde Serial Number 32465 (#11).

l. Sonde #12.

This unit was utilized during the winter monitoring portion for temperature monitoring only. This instrument failed pre-deployment trials in the spring. It remained non-mission capable for the entire season. This unit is currently non-operational and its gas probe port is now capped and plugged. The oxygen sensor was substituted to keep another instrument running.

m. Sonde #13.

This instrument was used from May to August. With a single point of data outside of control (30 May) the instrument performed exceptionally. After August, it became non-mission capable when it was apparently damaged at Peck when this station was damaged.

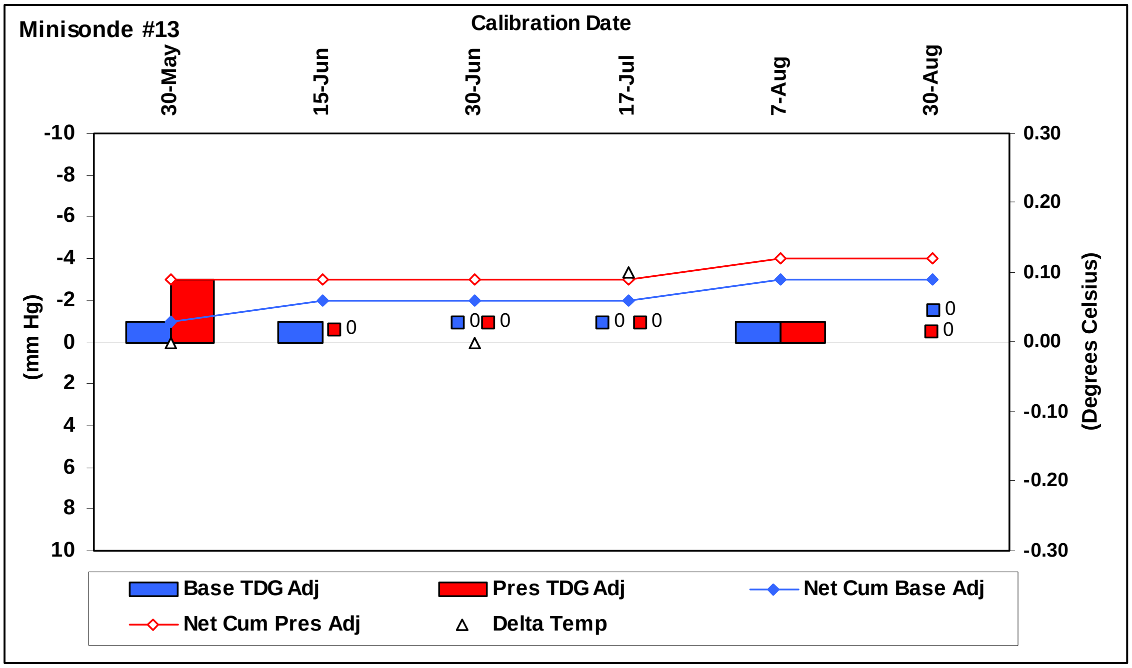

Figure 27. Control Chart for Hydrolab Minisonde Serial Number 32433 (#13).

n. Sonde #14.

This unit was used during the main season and performed within standards except in April. The instrument required a 3 mm Hg adjustment in April. This is not considered to be within CENWW's control limits but is still within the manufacturer's specifications. The error was discovered in April. During the April audit, it was determined that an error occurred in the barometric pressure reading from the mercury standard. This procedural error was corrected and the instrument was in standards the remaining portion of the year.

o. Sonde #15.

This instrument was not used in the FY 2000 monitoring season. It has an unstable pressure transducer and a usable DO sensor. It is still in a non-mission capable status. It will be overhauled in 2001.

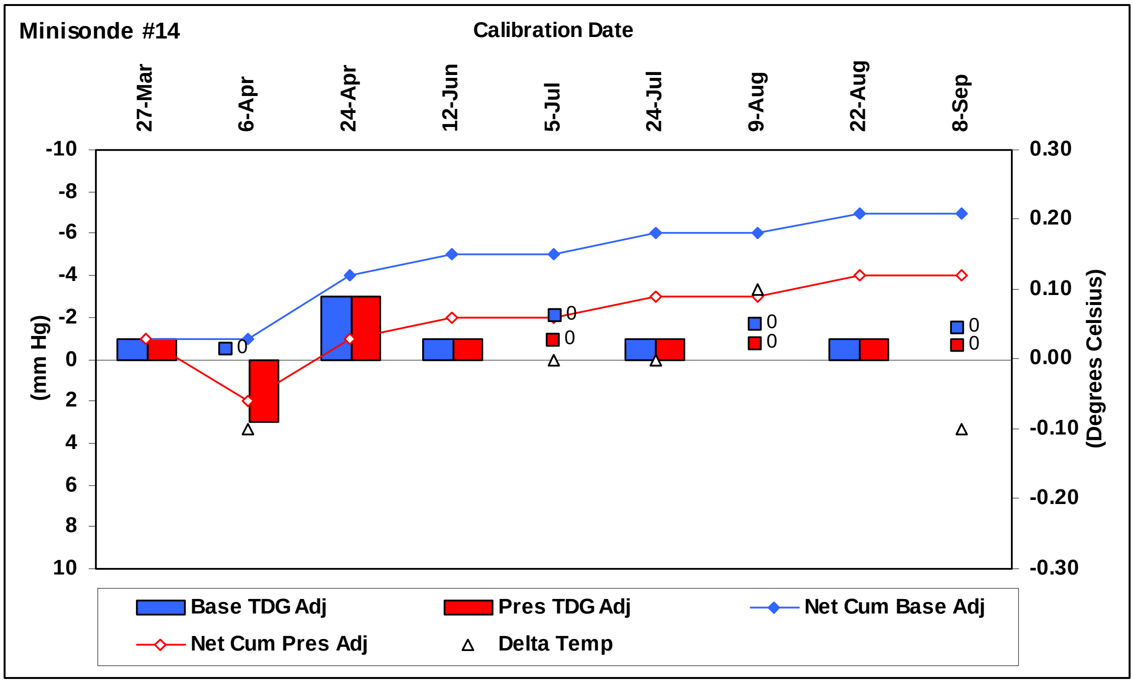

Figure 28. Control Chart for Hydrolab Minisonde Serial Number 32434 (#14).

p. Sonde #16.

This instrument performed quite well and was below the DQO's the entire year.

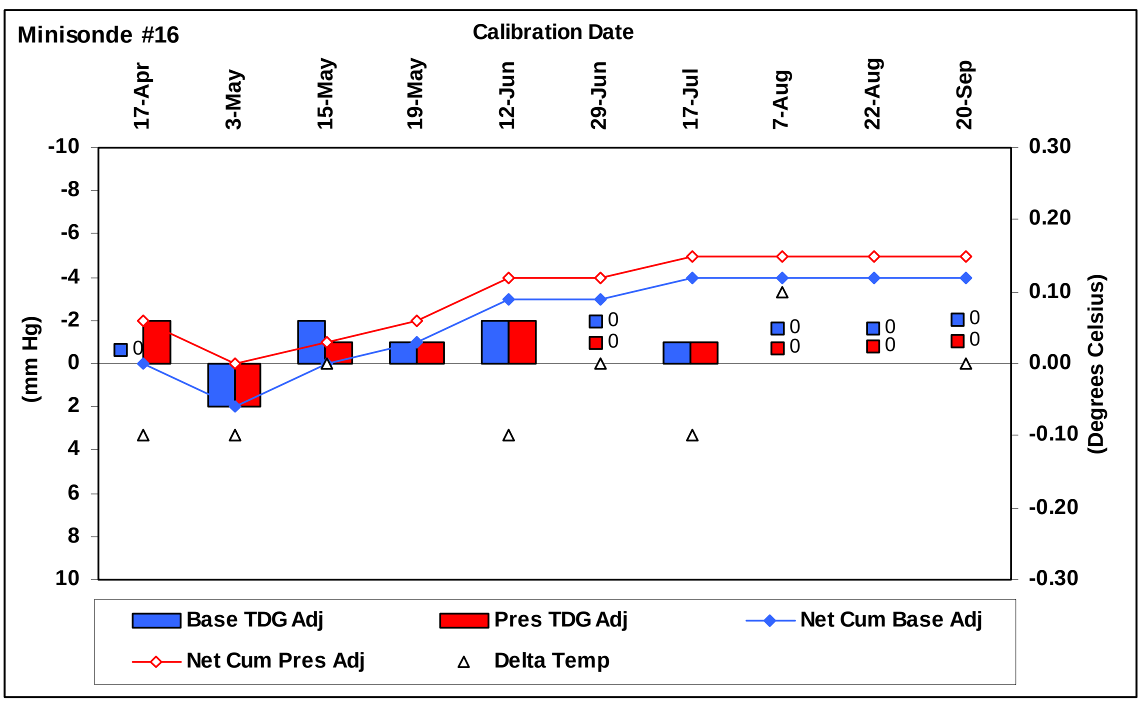

Figure 29. Control Chart for Hydrolab Minisonde Serial Number 32429 (#16).

q. **Sonde #17.**

This unit never passed QA/QC in the winter or the spring and was never deployed. It was sent to the manufacturer and was overhauled. It went through a test and evaluation period after coming back from the factory. It again failed to meet QA and only barely met specifications. It will function but it does meet the QA/QC for deployment. The manufacturer has not made additional repairs. The DO sensor is currently non-operational.

r. **Sonde #18.**

This unit started service in the month of March and performed consistently very well. In July, it was sent to the manufacturer for maintenance. It was tested in August and failed QC because the pressure transducer (TDG) was still outside the control limits. It is planned to send this unit back to the manufacturer for a complete overhaul. Until the July failure, the unit performed well and it is not planned to retire it until some time in 2006.

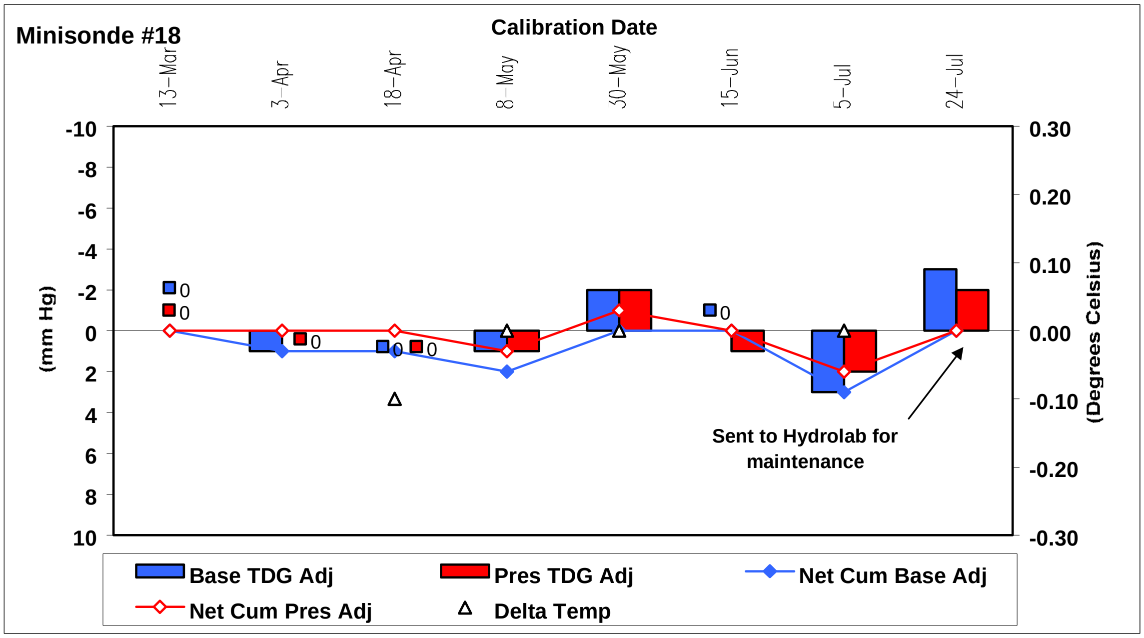

Figure 30. Control Chart for Hydrolab Minisonde Serial Number 32435 (#18).

s. **Sonde #19.**

This unit was used once in April and once in May. It is fairly new but the unit fails to calibrate properly. It requires repair but has not been repaired yet. We anticipated that it would be sent in for repair rather than replacement since it is only a few years old and has not seen much use.

t. **Sonde #20.**

This unit is one of the fleet's best sondes. It provided excellent service the entire season and provided better than required precision. The unit exceeded all specifications and QC limits. The unit is currently scheduled for an oxygen sensor rebuild and is expected to return to service in spring of 2001.

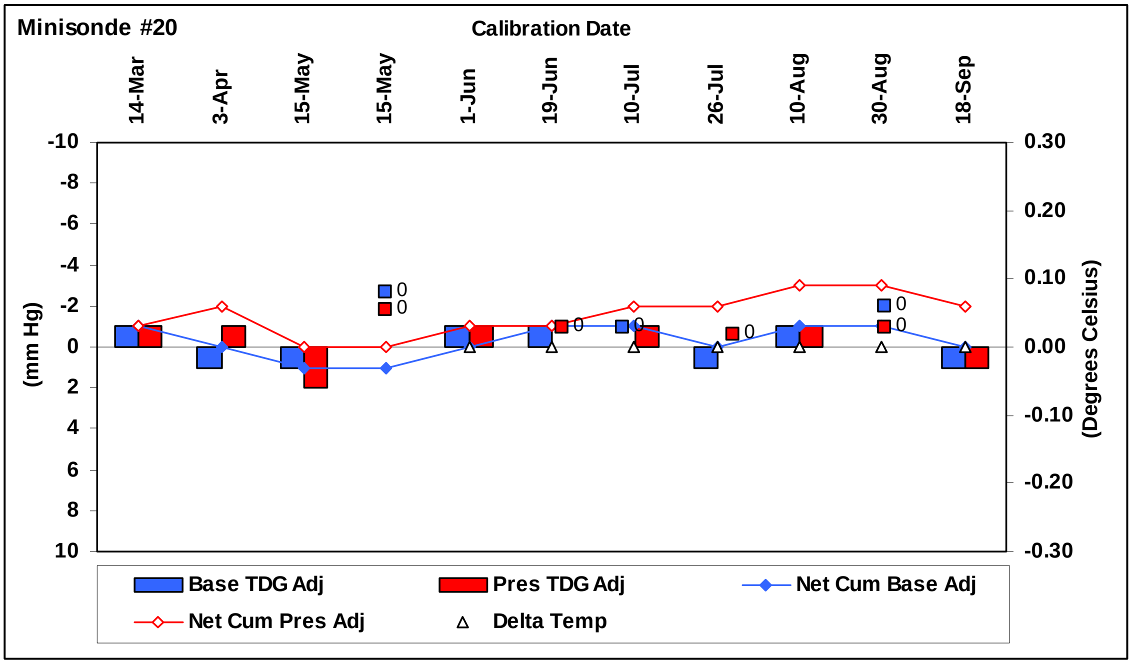

Figure 31. Control Chart for Hydrolab Minisonde Serial Number 32442 (#20).

u. **Sonde #21.**

This instrument performed exceptionally well with its TDG sensor. The temperature sensor has performed very well but appears to have drifted slightly downward. The temperature sensor is still currently within manufacturer's specifications.

v. **Sonde #22.**

The TDG sensor in this unit met specifications and passed QC limits throughout this season. Two outlying data points were observed of the standard but were still within the manufacturer's specifications. This is one of the newer units and has performed exceeding well this season.

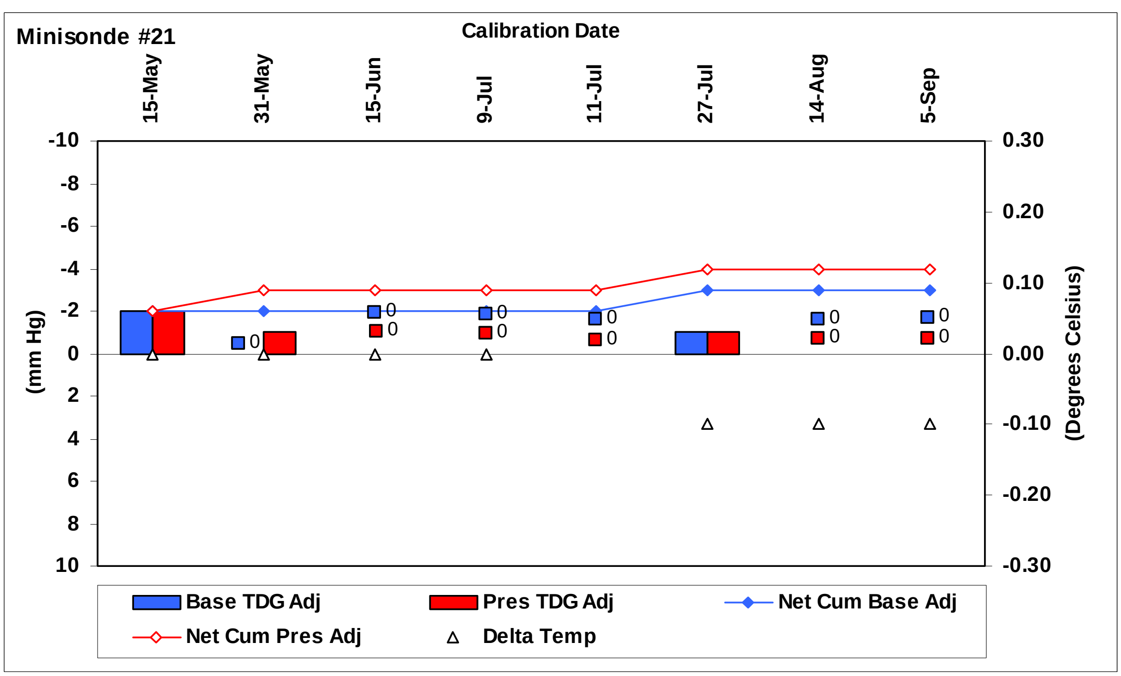

Figure 32. Control Chart for Hydrolab Minisonde Serial Number 32443 (#21).

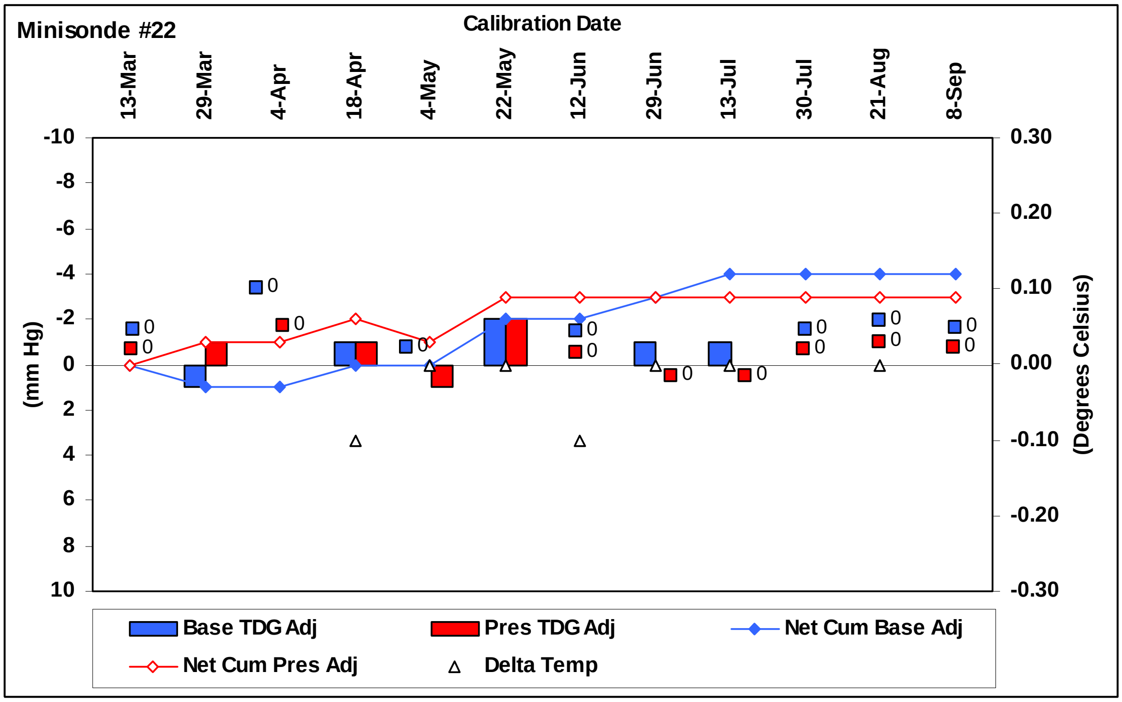

Figure 33. Control Chart for Hydrolab Minisonde Serial Number 32417 (#22).

w. Sonde #23.

This instrument is a new acquisition and was placed into service in September prior to going through trials due to lack of serviceable instruments. The instrument is one of the winter 2001 instruments and has proven to provide flawless data when measured against a standard.

x. Sonde #24.

This unit received severe water damage due to an O-ring failure and was written off as a total loss in February 2000.

y. Sonde #25.

This unit is a new acquisition and provided flawless TDG performance. The temperature sensor has been troublesome and failed QC on two occasions. The manufacturer's specification states that this thermister is just inside their specifications and will not warrant repair. This unit was not used in water year 2001 winter cycle and is scheduled for another temperature calibration at the factory.

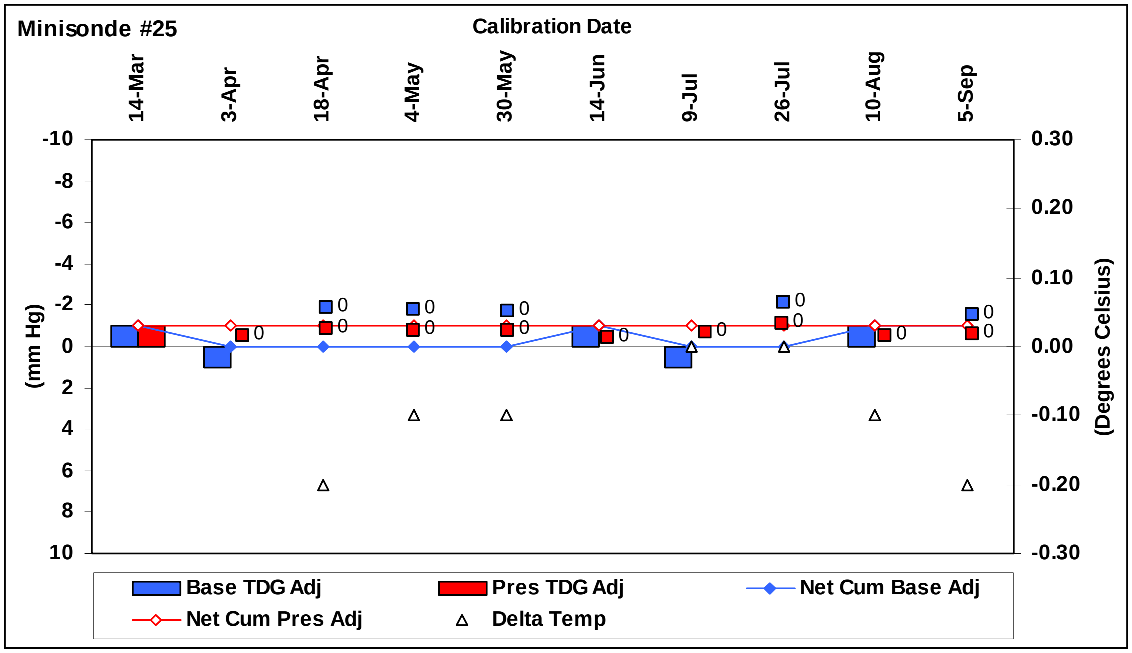

Figure 34. Control Chart for Hydrolab Minisonde Serial Number 36687 (#25).

z. Sonde #26.

This unit provided data within specifications for the entire water year. It appears that there was one data point outside control limits in early May. This may have been an anomaly since the error could not be repeated in the lab. Additional tests still did not render any reason for the dip in the lower control point. The rest of the year, it continued to provide temperature data within the manufacturer's specifications.

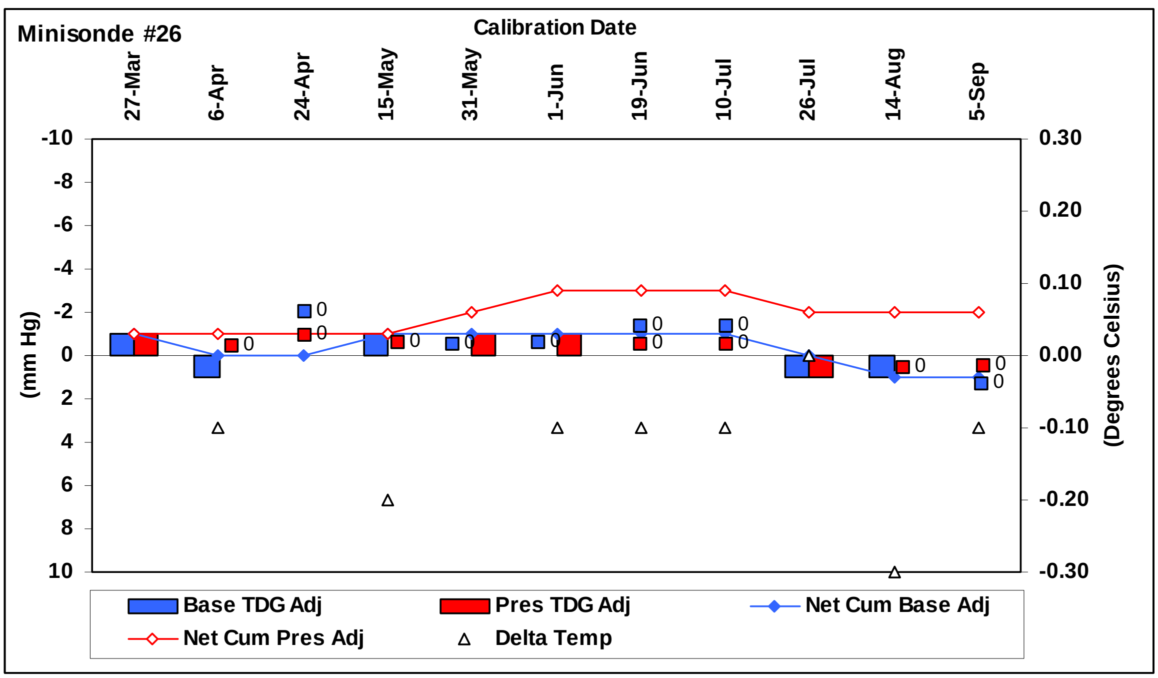

Figure 35. Control Chart for Hydrolab Minisonde Serial Number 36685 (#26).

aa. Sonde #27.

This unit is also a new acquisition and has performed well in the measurement of TDG pressure. As with other units in this batch (these are Minisonde mode 4a type sondes), the temperature probes are of lesser tolerances than the older units. This unit was kept in service until the end of the season because of the dwindling number of serviceable instruments. The temperature sensor was still within the manufacturer's specifications.

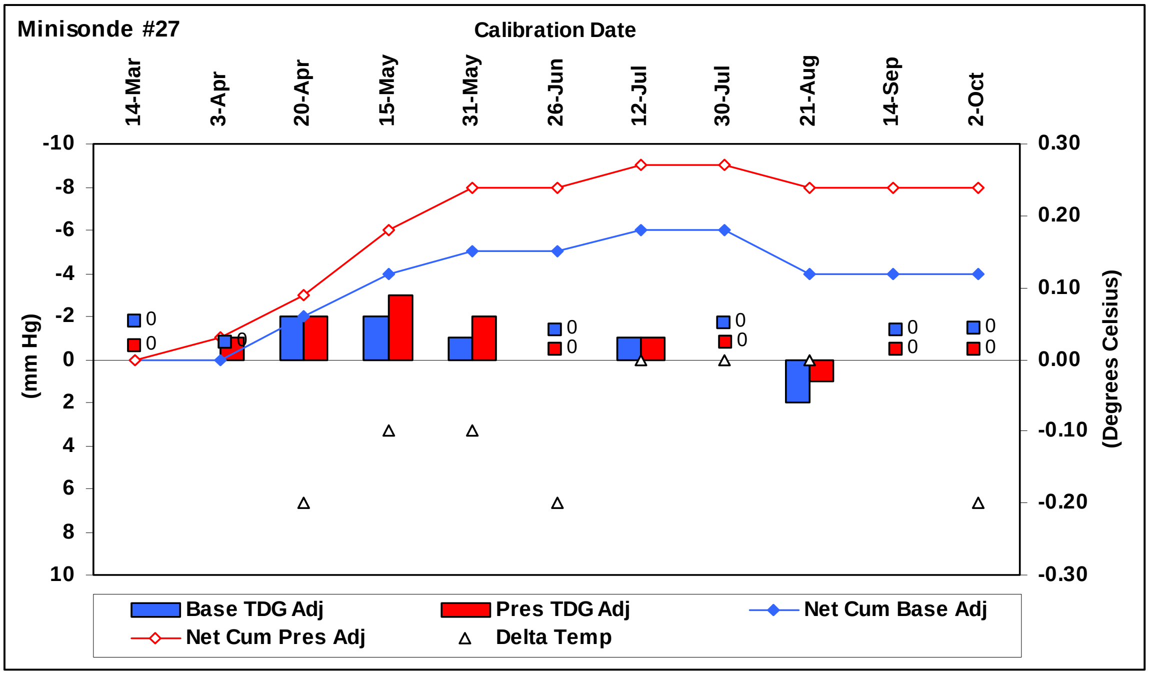

Figure 36. Control Chart for Hydrolab Minisonde Serial Number 36688 (#27).

bb. Sonde #28.

This instrument performed in the same manner as the sonde #27 instrument. Again, the thermister barely makes tolerances by manufacturer's specifications but does not meet the district QC limits, which reflect the DQO's. Again, this unit was kept in service due to the dwindling number of serviceable spares. It is currently used as a winter monitoring unit and its thermister is still barely within the manufacturer's specifications.

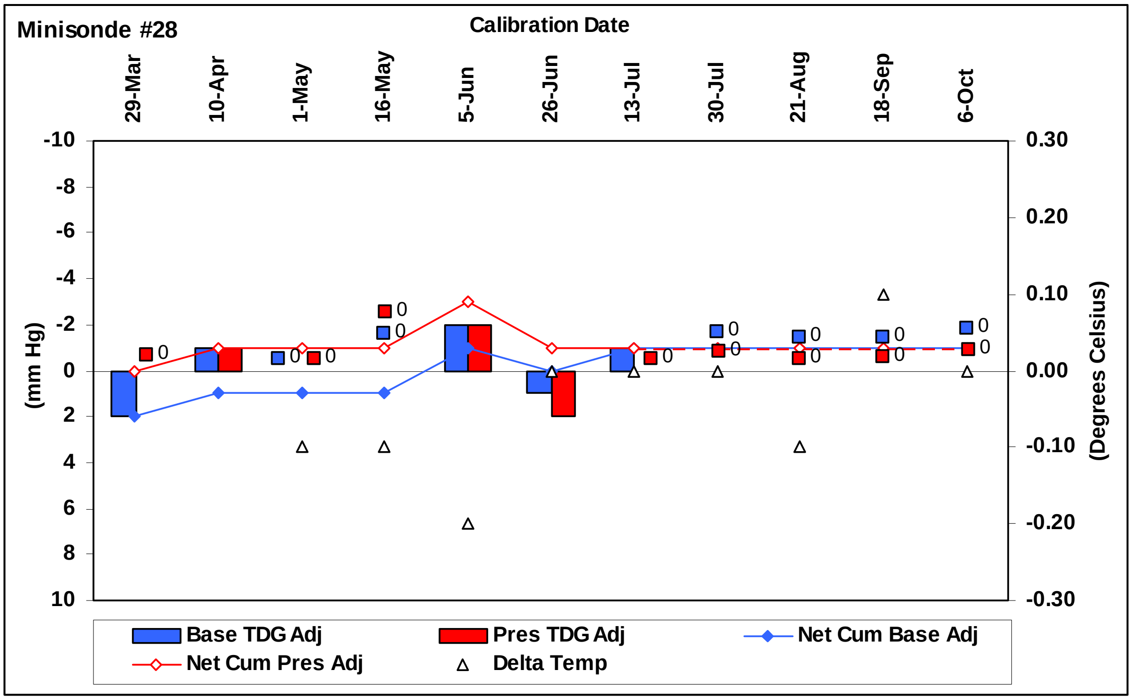

Figure 37. Control Chart for Hydrolab Minisonde Serial Number 36686 (#28).

DISCUSSION

This year, we focused on a critical evaluation of the instruments and spent considerable amounts of time evaluating the equipment for both the capability and operational aspects. After evaluation of the goals and objectives, it is very possible to obtain repeatable results for TDG within ±2 mm Hg of the standard when calibrated in the laboratory setting. In emergency situations, it may be possible to obtain tolerances of ±5 mm Hg in the field. Additional tests and evaluations would be required to calculate practical field-calibration precision levels. In practice, we have obtained this relative accuracy in field calibration. It is for this reason we recommend all calibrations take place in the laboratory with instruments.

In looking at making future improvements to instrumentation performance, we begin to ask what is reasonable and what is past the point of diminishing return. Improvements to the temperature precision and accuracy will increase the cost of the temperature sensor 10 times the current cost. This would include purchase and maintenance costs but would not reflect research and development (R&D) costs, which are not easy to estimate. The performance of TDG sensors is technologically at the extent of their design. Much more sensitive pressure transducers are available but cost and physical size of the devices make their adaptation problematic. Additionally, there is considerable cost associated with R&D. Any changes to the design of the TDG sensor would have to be in the software design. Since the sensors are coupled sondes with computational capability, improvements such as auto ranging and multi-point calibration could improve relative precision if non-standard curves are appropriate. All these improvements would provide a millimeter or two of improvement to the accuracy but probably no more than that.

In some instances, the station-specific charts reflect improvements or modifications made to the deployment stations or operating procedures. For example, the SOP's were modified in April and May 2000 to improve instrument precision. Heise instrumentation replaced Baumonometers and Sphygnometers as a means of pressurizing the sensor for precise calibration. Also, new barometer and temperature standards were purchased in late June 2000 and were incorporated into the system by mid-July. The resulting improvements to the precision of the instruments had a direct impact on the station QA/QC data. The relationships between instrument precision and station performance are visible on the charts. On many of the charts, there is an apparent decrease in data quality in May and from mid-June to mid-July. The reason for this apparent decrease is the 2-week lag time to replace all of the instruments in the system with those instruments calibrated utilizing the new procedures or standards. In all cases, the new standards resulted in better instrument precision and, therefore, better station performance.

There were many such improvements and changes made to the system throughout the year. For example, when damage to a deployment pipe prevented the retrieval of the in-place instrument, it became necessary to compare the instrument inside the pipe to a QC instrument deployed outside the pipe. Consequently, the in-place instrument remained in the pipe until repairs were made, causing some instruments to be deployed for several months rather than the scheduled 2-week cycle. This has clear implications for QC data collection. Other station pipes became filled with sediment at certain times of the year, requiring both instruments to be deployed outside the pipe. Lastly, failing or faulty instrument sensors can directly affect station data at times. It is not possible to completely filter the instrument performance data from the evaluation of the station data. Each of these events affected the station data in a unique way. A particular station chart may represent the cumulative effects of several such events, making it difficult to attribute disruptions in the trends to a particular source or to discern between the influence that an instrument has on the data in comparison to the influence of the station itself. In many cases, the instrument performance and modifications to the instrument calibration procedures affected the station comparison data to a greater extent than the actual station.

Future station improvements will focus on developing a station barometer calibration program, developing better instrument deployment methods, and improving circulation in and around the instruments.

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COPY AND USE PRIVLIGES

FULL CITATION

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DISCLAIMER

The use of models, brand names, or trade names does not constitute a recommendation or endorsement of the United State Government, Department of Defense, U.S. Army, or the Corps of Engineers. They are merely mentioned in the pursuit of scientific repeatability.

APPENDIX A

SONDE MAINTENANCE AND CALIBRATION RECORD

SONDE MAINTENANCE AND CALIBRATION RECORD (ER1130-2-234 & ER130-2-415)	1. MINISONDE ADMIN. #	2. HYDROLAB SERIAL #	3. BARCODE #	4. DATA SHEET COMPLETE (Initial when compelte) ________

SECTION 1 - PRE-DEPLOYMENT SONDE CALIBRATION

5. DATE	6. TIME	7. WALL BAROMETER	8. SURVEYOR 4 Bar	9. TDG MEMBRANE (check and circle all that apply) Dried Leak Check: Breath / Pressure Replaced
10. TDG STANDARD	11. Pre-Cal Base TDG	12. Pre-Cal Pres TDG	13. Cal'd Base TDG	14. Cal'd Pres TDG

15. Dissolved Oxygen Membrane (circle)	16. Dissolved Oxygen Standards Used To Calibrate Sonde
Replaced: Yes / No *24-hour Soak*: Yes / No	Air (Bar) = ________ mm/Hg **OR** Winkler = ________ mg/l
17. DO Lab Calibration (*Ambient Air Method*): BAR ________ mm, DO sat. = ________ % DO = ________ mg/l	18. DO Lab Calibration (*Winkler Titration Method*): BAR ________ mm/Hg, DO mg/l = ________ **AND** DO sat. = ________ %

19. NBS Temp:	**NOTES:**
20. Sonde Temp:	

SECTION 2 - STATION INFORMATION

21. STATION NAME	22. DATE	23. OFFICIAL TIME h (GMT)	24. DCP TIME h (GMT)	25. CHARGER TYPE	26. CHARGER STATUS
27. BATTERY DATE: / 28. BATTERY VOLTAGE: v		31. BAROM. BARCODE #	32. SURVEYOR 4 BAR mm	33. STATION BAR (Initial) mm	34. STATION BAR (Cal'd) mm
29. FUSE STATUS ( ) 30. SUTRON STATUS ( )		35. STATION DUE DATE	36. TECHNICIAN NAME	STATION NOTES:	

SECTION 3 - SONDE DEPLOYMENT DATA

37. SITE ARRIVAL TIME	38. DO Field Calibration (*Ambient Air Method*): BAR ________ mm, DO% = ________ % DO = ________ mg/l	39. DO Field Calibration (*Winkler Titration Method*): BAR ________ mm, DO mg/l = ________ DO sat. = ________ %

40. PRE-DEPLOYMENT HYDROLAB CHECKS Operation ( ) TDG Response ( ) DO Field Calibrated ( )	41. DEPLOYMENT TIME In-Pipe / Out-of-Pipe	42. STABLE READINGS ( )	43. TIME OF QC READINGS

Target TDG	44. QA/QC SONDE	45. TDG	46. DO %sat.	47. DO mg/l	48. TEMP °C
Target DO mg/L	49. IN PLACE SONDE	50. TDG	51. DO %sat.	52. DO mg/l	53. TEMP °C

54. TDG CHECK (final)	55. CHARGER STATUS (final)	56. DEPARTURE TIME	57. TECHNICIAN

ADDITIONAL NOTES:

SECTION 4 - POST-DEPLOYMENT SONDE CALIBRATION CHECK

58. Proper Data Sheet Yes / No	59. Check Date / Time	60. WALL BAROMETER	61. SURVEYOR 4 Bar	62. Physical Condition:	63. Sonde Cleaned? Yes / No

66. DO Lab Check (*Ambient Air Method*): BAR ________ mm, DO sat. = ________ % DO = ________ mg/l	67. TDG STANDARD mm/Hg	68. Baseline TDG Check	69. Pressurized Check
70. DO Lab Calibration (*Winkler Titration Method*): BAR ________ mm/Hg, DO mg/l = ________ **AND** DO sat. = ________ %		71. NBS Standard °C	72. Sonde Temp Check °C

ADDITIONAL NOTES:

MCQO - McNary Forebay, OR, **MCQW** - McNary Forebay, WA, **MCPW** - McNary Tailwater, **PAQW** - Pasco Station, **IHR** - Ice Harbor Forebay, **IDSW** - Ice Harbor Tailwater, **LMN** - Lower Monumental Forebay, **LMNW** - Lower Monumental Tailwater, **LGS** - Little Goose Forebay, **LGSW** - Little Goose Tailwater, **LWG** Lower Granite Forebay, **LGNW** - Lower Granite Tailwater, **LEWI** - Lewiston, **ANQW** - Anatone, **PEKI** - Peck, **DWQI** - Dworshak

APPENDIX B

MONTHLY SORTED SONDE DATA

Monthly Sorted Sonde Data

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
March 2000					
	3/13/00	7	0	0	
	3/13/00	9	0	0	
	3/13/00	11	0	0	
	3/13/00	18	0	0	
	3/13/00	22	0	0	
	3/14/00	20	1	1	
	3/14/00	25	1	1	
	3/14/00	27	0	0	
	3/27/00	1	-2	-2	
	3/27/00	10	1	-5	
	3/27/00	14	1	1	
	3/27/00	26	1	1	
	3/29/00	5	0	0	
	3/29/00	9	-2	0	
	3/29/00	11	0	2	
	3/29/00	22	-1	1	
	3/29/00	28	-2	0	
April 2000					
	4/ 3/00	7	0	1	
	4/ 3/00	18	-1	0	
	4/ 3/00	20	-1	1	
	4/ 3/00	25	-1	0	
	4/ 3/00	27	0	1	
	4/ 4/00	1	0	1	
	4/ 4/00	22	0	0	
	4/ 6/00	9	0	0	0.00
	4/ 6/00	10	-1	0	0.10
	4/ 6/00	14	0	-3	0.10

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	4/ 6/00	26	-1	0	0.10
	4/10/00	3	1	2	
	4/10/00	8	1	2	
	4/10/00	11	1	1	
	4/10/00	28	1	1	
	4/17/00	2	4	4	0.00
	4/17/00	5	1	1	0.00
	4/17/00	16	0	2	0.10
	4/18/00	1	1	1	0.10
	4/18/00	18	0	0	0.10
	4/18/00	22	1	1	0.10
	4/18/00	25	0	0	0.20
	4/20/00	3	1	1	0.10
	4/20/00	7	1	1	0.10
	4/20/00	27	2	2	0.20
	4/24/00	9	0	0	
	4/24/00	10	1	1	
	4/24/00	14	3	3	
	4/24/00	26	0	0	
May 2000					
	5/ 1/00	8	0	0	0.10
	5/ 1/00	11	0	0	0.00
	5/ 1/00	15	5	9	0.10
	5/ 1/00	28	0	0	0.10
	5/ 3/00	2	-1	-1	0.00
	5/ 3/00	6	-2	-2	0.00
	5/ 3/00	16	-2	-2	0.10
	5/ 4/00	1	-1	-1	0.10
	5/ 4/00	5	-1	-1	0.00
	5/ 4/00	22	0	-1	0.00
	5/ 4/00	25	0	0	0.10
	5/ 8/00	3	-2	-2	0.00

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	5/ 8/00	7	-3	-3	0.00
	5/ 8/00	13	-5	0	0.00
	5/ 8/00	18	-1	-1	0.00
	5/15/00	16	2	1	0.00
	5/15/00	20	-1	-2	
	5/15/00	20	0	0	
	5/15/00	21	2	2	0.00
	5/15/00	26	1	0	0.20
	5/15/00	27	2	3	0.10
	5/16/00	28	0	0	0.10
	5/17/00	8	-1	-1	
	5/17/00	11	0	0	0.10
	5/17/00	15	0	1	0.00
	5/18/00	2	2	2	0.10
	5/18/00	6	2	2	0.00
	5/19/00	16	1	1	
	5/22/00	1	1	2	
	5/22/00	5	2	2	
	5/22/00	22	2	2	0.00
	5/30/00	3	1	2	0.00
	5/30/00	7	4	4	0.00
	5/30/00	13	1	3	0.00
	5/30/00	18	2	2	0.00
	5/30/00	25	0	0	0.10
	5/31/00	10	0	1	0.00
	5/31/00	21	0	1	0.00
	5/31/00	26	0	1	
	5/31/00	27	1	2	0.10
June 2000					
	6/ 1/00	8	2	1	0.00
	6/ 1/00	20	1	1	0.00
	6/ 1/00	26	0	1	0.10

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	6/ 5/00	2	0	1	0.00
	6/ 5/00	11	1	1	0.10
	6/ 5/00	15	0	0	0.10
	6/ 5/00	28	2	2	0.20
	6/12/00	1	-3	-3	0.10
	6/12/00	5	0	0	0.00
	6/12/00	14	1	1	
	6/12/00	16	2	2	0.10
	6/12/00	22	0	0	0.10
	6/14/00	3	0	0	
	6/14/00	7	0	0	
	6/14/00	25	1	0	
	6/15/00	7	0	0	
	6/15/00	13	1	0	
	6/15/00	18	0	-1	
	6/15/00	21	0	0	0.00
	6/15/00	10	0	0	0.00
	6/19/00	8	0	0	0.00
	6/19/00	20	1	0	0.00
	6/19/00	26	0	0	0.10
	6/26/00	2	0	-1	0.10
	6/26/00	11	-1	-1	0.00
	6/26/00	15	-2	-1	0.00
	6/26/00	27	0	0	0.20
	6/26/00	28	-1	-2	0.00
	6/29/00	1	1	1	
	6/29/00	1	1	1	0.10
	6/29/00	3	2	3	0.00
	6/29/00	5	-1	-1	0.00
	6/29/00	16	0	0	0.00
	6/29/00	22	1	0	0.00
	6/30/00	13	0	0	0.00

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
July 2000					
	7/ 5/00	7	-1	0	-0.10
	7/ 5/00	10	-1	-1	0.00
	7/ 5/00	14	0	0	0.00
	7/ 5/00	18	-3	-2	0.00
	7/ 9/00	21	0	0	0.00
	7/ 9/00	25	-1	0	0.00
	7/10/00	8	0	0	0.10
	7/10/00	20	0	1	0.00
	7/10/00	26	0	0	0.10
	7/11/00	21	0	0	
	7/12/00	2	1	1	0.10
	7/12/00	11	1	2	-0.10
	7/12/00	27	1	1	0.00
	7/13/00	5	0	0	0.00
	7/13/00	22	1	0	0.00
	7/13/00	28	1	0	0.00
	7/17/00	1	-2	-1	0.10
	7/17/00	3	-2	-2	0.00
	7/17/00	13	0	0	-0.10
	7/17/00	16	1	1	0.10
	7/24/00	7	0	0	0.10
	7/24/00	10	-1	-1	0.00
	7/24/00	14	1	1	0.00
	7/24/00	18	3	2	
	7/26/00	8	-1	-1	0.00
	7/26/00	20	-1	0	0.00
	7/26/00	25	0	0	0.00
	7/26/00	26	-1	-1	0.00
	7/27/00	2	0	0	0.10
	7/27/00	11	0	0	0.10
	7/27/00	21	1	1	0.10

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	7/30/00	5	0	0	0.00
	7/30/00	22	0	0	
	7/30/00	27	0	0	0.00
	7/30/00	28	0	0	0.00
August 2000					
	8/ 7/00	1	1	1	
	8/ 7/00	3	0	0	
	8/ 7/00	13	1	1	
	8/ 7/00	16	0	0	-0.10
	8/ 9/00	14	0	0	-0.10
	8/10/00	7	0	0	0.00
	8/10/00	8	0	0	
	8/10/00	10	-1	1	0.00
	8/10/00	20	1	1	0.00
	8/10/00	25	1	0	0.10
	8/14/00	2	0	0	0.10
	8/14/00	11	-1	-1	0.00
	8/14/00	21	0	0	0.10
	8/14/00	26	-1	0	0.30
	8/21/00	5	-1	-1	0.10
	8/21/00	22	0	0	0.00
	8/21/00	27	-2	-1	0.00
	8/21/00	28	0	0	0.10
	8/22/00	7	0	0	
	8/22/00	14	1	1	
	8/22/00	16	0	0	
	8/23/00	10	2	2	0.00
	8/24/00	8	1	1	
	8/30/00	1	0	0	0.10
	8/30/00	13	0	0	
	8/30/00	20	0	0	0.00
September 2000					

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	9/ 5/00	2	0	-1	
	9/ 5/00	11	0	-1	0.10
	9/ 5/00	21	0	0	0.10
	9/ 5/00	25	0	0	0.20
	9/ 5/00	26	0	0	0.10
	9/ 7/00	3	0	0	0.00
	9/ 8/00	8	0	0	0.00
	9/ 8/00	10	0	0	
	9/ 8/00	14	0	0	0.10
	9/ 8/00	22	0	0	
	9/14/00	7	0	0	
	9/14/00	27	0	0	
	9/18/00	20	-1	-1	0.00
	9/18/00	23	0	0	0.00
	9/18/00	28	0	0	-0.10
	9/19/00	2	0	0	0.00
	9/19/00	10	0	0	0.00
	9/20/00	16	0	0	0.00
	9/21/00	7	0	0	0.10
October 2000					
	10/ 2/00	27	0	0	0.20
	10/ 6/00	23	0	0	0.00
	10/ 6/00	28	0	0	0.00

APPENDIX C

MONTHLY SORTED STATION DATA

Monthly Sorted Station Data

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
March 2000						
	3/14/00	MCQO	22	27	-4	0.00
	3/14/00	MCQW	11	20	0	0.00
	3/14/00	MCPW	9	25		
	3/15/00	IDSW	18	1	6	-0.07
	3/15/00	IHR	7	10	-1	-0.01
	3/16/00	DWQI	25	26	0	0.03
	3/16/00	LWG	27	5	0	0.05
	3/16/00	LGNW	20	14	5	-0.04
	3/28/00	MCQW	10	11	1	0.02
	3/28/00	MCQO	14	22	-2	0.00
	3/28/00	MCPW	26	9	-1	0.05
	3/28/00	PAQW	1	28	0	-0.10
	3/29/00	IDSW	9	18	3	-0.11
	3/30/00	IHR	22	7	-3	0.00
	3/31/00	DWQI	5	25	-2	-0.20
	3/31/00	LGNW	11	20	0	0.00
	3/31/00	LWG	28	27	1	-0.11
April 2000						
	4/ 4/00	PAQW	18	1	4	-0.06
	4/ 4/00	IDSW	20	9	2	0.06
	4/ 4/00	IHR	7	22	2	-0.02
	4/ 4/00	MCQW	1	10	-4	-0.08
	4/ 5/00	MCQO	22	14	-6	-0.02
	4/ 5/00	MCPW	25	26	1	-0.02
	4/ 7/00	LGNW	14	11	-1	0.04
	4/ 7/00	LGS	10	3	0	-0.10
	4/ 7/00	LGSW	26	8	-3	-0.04
	4/ 7/00	LWG	9	28	0	-0.10
	4/10/00	LMNW	3	19		
	4/10/00	LMN	27	2	0	0.03
	4/11/00	DWQI	8	5	3	0.12
	4/11/00	LEWI	28	16	-1	0.16
	4/11/00	ANQW	11	6	-7	-0.09
	4/18/00	PAQW	2	18	0	0.06

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	4/18/00	ANQW	16	1	2	0.05
	4/19/00	LMN	22	27	2	-0.01
	4/19/00	IDSW	5	20	0	-0.03
	4/19/00	LMNW	1	3	1	0.08
	4/19/00	IHR	25	7	1	0.01
	4/21/00	LGS	18	10	1	-0.08
	4/21/00	LGSW	3	26	-1	-0.06
	4/21/00	LGNW	7	14	2	0.00
	4/21/00	LWG	27	9	2	0.11
	4/25/00	DWQI	9	8	1	-0.13
	4/26/00	LEWI	26	28	6	-0.06
	4/26/00	DWQI	14	9	2	0.10
	4/26/00	ANQW	10	11	0	0.05
May 2000						
	5/ 2/00	MCQW	11	16	1	-0.05
	5/ 2/00	PAQW	8	2	0	0.01
	5/ 2/00	MCPW	15	19	3	0.05
	5/ 2/00	MCQO	28	6	-2	0.15
	5/ 3/00	IHR	16	25	0	0.00
	5/ 4/00	LMNW	2	1	0	0.05
	5/ 4/00	LMN	6	22	3	-0.10
	5/ 5/00	LGSW	5	3	-1	-0.01
	5/ 5/00	LGNW	1	7	-2	-0.01
	5/ 5/00	LGS	25	18	-1	0.07
	5/ 5/00	LWG	22	27	-4	-0.01
	5/ 9/00	LEWI	13	26	0	-0.10
	5/ 9/00	PEKI	7	20	-4	0.07
	5/ 9/00	DWQI	3	14	-1	-0.09
	5/ 9/00	ANQW	18	10	-1	-0.01
	5/16/00	MCQW	21	11	-3	0.04
	5/16/00	MCQO	27	28	0	-0.14
	5/16/00	MCPW	26	15	-4	0.03
	5/17/00	IHR	28	16	-1	0.08
	5/17/00	PAQW	16	8	-1	0.00
	5/17/00	IDSW	20	19	2	0.06
	5/18/00	LMNW	8	2	4	0.05
	5/18/00	LMN	20	6	3	0.07
	5/19/00	LGNW	2	1	1	0.00

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	5/19/00	LGSW	11	5	14	0.03
	5/19/00	LWG	6	22	3	-0.10
	5/19/00	LGS	15	25	5	-0.05
	5/23/00	DWQI	22	3	1	0.04
	5/23/00	PEKI	16	7	3	0.02
	5/23/00	ANQW	1	18	0	0.06
	5/24/00	LEWI	5	13	2	0.03
	5/31/00	LMNW	10	8	6	-0.02
	5/31/00	MCPW	7	26	-2	0.01
	5/31/00	PAQW	13	10	-1	-0.10
	5/31/00	MCQO	25	27	-4	0.04
	5/31/00	MCQW	3	21	1	-0.07
June 2000						
	6/ 1/00	IDSW	26	19	-4	-0.10
	6/ 1/00	IHR	21	28	1	-0.10
	6/ 1/00	LMN	18	20	3	0.02
	6/ 2/00	LGNW	27	2	3	0.02
	6/ 2/00	LWG	26	6	-1	0.15
	6/ 2/00	LGS	20	15		0.04
	6/ 2/00	LGSW	8	11	2	0.11
	6/ 6/00	DWQI	2	22	3	0.01
	6/ 6/00	ANQW	15	1	10	-0.05
	6/ 7/00	LEWI	28	5	0	0.10
	6/13/00	MCQO	22	25	-1	-0.03
	6/13/00	MCQW	1	3	-5	0.03
	6/13/00	MCPW	5	7	-2	-0.06
	6/14/00	PAQW	16	13	-2	0.12
	6/14/00	IDSW	7	19	1	0.11
	6/14/00	IHR	14	21	0	0.00
	6/15/00	LMNW	25	10	-1	0.08
	6/15/00	LMN	3	18	2	-0.02
	6/16/00	LGS	18	20	1	-0.01
	6/16/00	LWG	7	26	-3	-0.07
	6/16/00	PEKI	11	16	3	-0.04
	6/16/00	LGSW	13	8	-1	-0.15
	6/16/00	LGNW	10	27	6	0.02
	6/20/00	PEKI	8	11	-2	0.05
	6/20/00	LEWI	20	28	1	-0.03

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	6/20/00	DWQI	21	2	-5	0.00
	6/21/00	ANQW	26	15	-7	0.04
	6/27/00	MCQO	27	22	0	-0.17
	6/27/00	MCQW	2	1	1	0.12
	6/27/00	MCPW	11	5	-4	0.04
	6/28/00	PAQW	15	16	4	-0.06
	6/29/00	LMN	22	3	0	0.00
	6/29/00	LMNW	28	25	1	0.02
	6/29/00	IDSW	1	19	1	0.02
	6/29/00	IHR	5	14	1	-0.11
	6/30/00	LWG	1	7	0	0.00
	6/30/00	LGSW	3	13	2	0.05
	6/30/00	LGNW	16	10	0	0.09
	6/30/00	LGS	13	18	3	-0.02
July 2000						
	7/ 6/00	DWQI	18	21	0	0.01
	7/ 6/00	LEWI	10	20	0	-0.09
	7/ 6/00	ANQW	7	26	-4	0.06
	7/ 6/00	PEKI	14	8	-1	-0.01
	7/11/00	MCPW	26	11	-5	0.02
	7/11/00	MCQO	8	27	-4	0.03
	7/11/00	MCQW	20	2	0	-0.21
	7/11/00	PAQW	25	15		
	7/12/00	IDSW	21	19	-1	0.09
	7/12/00	IHR	21	5	-1	0.01
	7/13/00	LMNW	11	28	6	0.00
	7/13/00	LMN	2	22	0	0.04
	7/14/00	LWG	22	1	0	-0.02
	7/14/00	LGNW	27	16	0	-0.04
	7/14/00	LGSW	5	3	0	-0.03
	7/14/00	LGS	28	13	0	-0.12
	7/18/00	DWQI	1	18	0	-0.03
	7/18/00	LEWI	13	10	-1	-0.09
	7/18/00	PEKI	3	14	1	-0.06
	7/19/00	ANQW	16	7	-1	0.08
	7/25/00	MCQO	7	8	0	-0.01
	7/25/00	MCQW	10	20	-3	-0.02
	7/25/00	MCPW	14	26	-4	0.01

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	7/26/00	PAQW	18	25	0	-0.12
	7/27/00	LMNW	8	11	-1	0.06
	7/27/00	IDSW	25	19		
	7/27/00	IHR	20	21	0	0.05
	7/28/00	LGSW	11	5	0	0.03
	7/28/00	LWG	2	22	0	-0.02
	7/28/00	LGNW	26	27	1	-0.03
	7/28/00	LGS	21	28	0	-0.05
	7/30/00	LEWI	5	13	0	0.05
	7/30/00	ANQW	27	16		
	7/31/00	PEKI	28	3	0	0.13
	7/31/00	DWQI	22	1	1	0.02
August 2000						
	8/ 9/00	MCQW	1	10	-1	-0.02
	8/ 9/00	MCPW	3	14	0	-0.07
	8/ 9/00	MCQO	13	7	1	-0.11
	8/ 9/00	IDSW	16	25	1	-0.13
	8/ 9/00	IHR	14	20	7	0.14
	8/10/00	LMN	10	19	0	0.00
	8/10/00	LMNW	7	8	0	0.02
	8/11/00	LWG	25	2	0	-0.05
	8/11/00	LGSW	8	11	0	0.01
	8/11/00	LGNW	20	26	0	0.00
	8/15/00	PEKI	11	28	1	-0.11
	8/15/00	DWQI	2	22		
	8/16/00	LEWI	21	5	0	0.00
	8/16/00	ANQW	26	27	-1	-0.10
	8/22/00	IDSW	22	16	0	0.01
	8/22/00	LMN	27	10	0	-0.11
	8/22/00	LMNW	5	7	1	-0.15
	8/22/00	IHR	28	14	-5	0.07
	8/23/00	LGS	10	19	0	-0.03
	8/23/00	LGSW	7	8	0	-0.04
	8/23/00	LWG	16	25	2	-0.02
	8/23/00	LGNW	14	20	0	0.04
	8/24/00	MCQW	8	1	0	0.01
	8/30/00	PEKI	13	11	0	0.08
	8/30/00	DWQI	1	2	0	-0.04

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	8/30/00	ANQW	20	26	0	-0.05
September 2000						
	9/ 6/00	MCQO	11	19	-3	0.06
	9/ 6/00	PAQW	25	17	0	0.02
	9/ 6/00	MCPW	2	3	-1	0.02
	9/ 6/00	MCQW	21	8	0	-0.01
	9/ 7/00	LGNW	26	14	-1	-0.02
	9/ 7/00	LGS	3	10	0	-0.04
	9/ 7/00	LGSW	16	7	1	-0.02
	9/ 8/00	LMN	8	27	0	0.02
	9/ 8/00	IHR	22	28	-2	-0.06
	9/ 8/00	LMNW	14	23	0	0.08
	9/ 8/00	IDSW	10	22	3	0.00
	9/14/00	ANQW	7	20	4	0.09
	9/14/00	DWQI	27	1	4	0.02
	9/19/00	MCPW	28	2	0	0.02
	9/19/00	IDSW	20	10	0	-0.01
	9/19/00	MCQO	10	11	0	0.06
	9/19/00	IHR	23	22	-4	-0.06
	9/19/00	MCQW	2	21	-1	-0.04
	9/21/00	DWQI	7	27	0	-0.04
October 2000						
	10/ 6/00	MCPW	27	28	0	-0.07
	10/ 6/00	MCQW	23	2	0	0.01
	10/ 6/00	MCQO	28	10	-2	0.10

APPENDIX D

SONDE-SPECIFIC DATA

Sonde Specific Data

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
1				
	3/27/00	-2	-2	
	4/ 4/00	0	1	
	4/18/00	1	1	0.10
	5/ 4/00	-1	-1	0.10
	5/22/00	1	2	
	6/12/00	-3	-3	0.10
	6/29/00	1	1	
	6/29/00	1	1	0.10
	7/17/00	-2	-1	0.10
	8/ 7/00	1	1	
	8/30/00	0	0	0.10
2				
	4/17/00	4	4	0.00
	5/ 3/00	-1	-1	0.00
	5/18/00	2	2	0.10
	6/ 5/00	0	1	0.00
	6/26/00	0	-1	0.10
	7/12/00	1	1	0.10
	7/27/00	0	0	0.10
	8/14/00	0	0	0.10
	9/ 5/00	0	-1	
	9/19/00	0	0	0.00
3				
	4/10/00	1	2	
	4/20/00	1	1	0.10
	5/ 8/00	-2	-2	0.00
	5/30/00	1	2	0.00
	6/14/00	0	0	

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	6/29/00	2	3	0.00
	7/17/00	-2	-2	0.00
	8/ 7/00	0	0	
	9/ 7/00	0	0	0.00
5				
	3/29/00	0	0	
	4/17/00	1	1	0.00
	5/ 4/00	-1	-1	0.00
	5/22/00	2	2	
	6/12/00	0	0	0.00
	6/29/00	-1	-1	0.00
	7/13/00	0	0	0.00
	7/30/00	0	0	0.00
	8/21/00	-1	-1	0.10
6				
	5/ 3/00	-2	-2	0.00
	5/18/00	2	2	0.00
7				
	3/13/00	0	0	
	4/ 3/00	0	1	
	4/20/00	1	1	0.10
	5/ 8/00	-3	-3	0.00
	5/30/00	4	4	0.00
	6/14/00	0	0	
	6/15/00	0	0	
	7/ 5/00	-1	0	-0.10
	7/24/00	0	0	0.10
	8/10/00	0	0	0.00
	8/22/00	0	0	
	9/14/00	0	0	
	9/21/00	0	0	0.10

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
8				
	4/10/00	1	2	
	5/ 1/00	0	0	0.10
	5/17/00	-1	-1	
	6/ 1/00	2	1	0.00
	6/19/00	0	0	0.00
	7/10/00	0	0	0.10
	7/26/00	-1	-1	0.00
	8/10/00	0	0	
	8/24/00	1	1	
	9/ 8/00	0	0	0.00
9				
	3/13/00	0	0	
	3/29/00	-2	0	
	4/ 6/00	0	0	0.00
	4/24/00	0	0	
10				
	3/27/00	1	-5	
	4/ 6/00	-1	0	0.10
	4/24/00	1	1	
	5/31/00	0	1	0.00
	6/15/00	0	0	0.00
	7/ 5/00	-1	-1	0.00
	7/24/00	-1	-1	0.00
	8/10/00	-1	1	0.00
	8/23/00	2	2	0.00
	9/ 8/00	0	0	
	9/19/00	0	0	0.00
11				
	3/13/00	0	0	
	3/29/00	0	2	

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	4/10/00	1	1	
	5/ 1/00	0	0	0.00
	5/17/00	0	0	0.10
	6/ 5/00	1	1	0.10
	6/26/00	-1	-1	0.00
	7/12/00	1	2	-0.10
	7/27/00	0	0	0.10
	8/14/00	-1	-1	0.00
	9/ 5/00	0	-1	0.10
13				
	5/ 8/00	-5	0	0.00
	5/30/00	1	3	0.00
	6/15/00	1	0	
	6/30/00	0	0	0.00
	7/17/00	0	0	-0.10
	8/ 7/00	1	1	
	8/30/00	0	0	
14				
	3/27/00	1	1	
	4/ 6/00	0	-3	0.10
	4/24/00	3	3	
	6/12/00	1	1	
	7/ 5/00	0	0	0.00
	7/24/00	1	1	0.00
	8/ 9/00	0	0	-0.10
	8/22/00	1	1	
	9/ 8/00	0	0	0.10
15				
	5/ 1/00	5	9	0.10
	5/17/00	0	1	0.00
	6/ 5/00	0	0	0.10

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	6/26/00	-2	-1	0.00
16				
	4/17/00	0	2	0.10
	5/ 3/00	-2	-2	0.10
	5/15/00	2	1	0.00
	5/19/00	1	1	
	6/12/00	2	2	0.10
	6/29/00	0	0	0.00
	7/17/00	1	1	0.10
	8/ 7/00	0	0	-0.10
	8/22/00	0	0	
	9/20/00	0	0	0.00
18				
	3/13/00	0	0	
	4/ 3/00	-1	0	
	4/18/00	0	0	0.10
	5/ 8/00	-1	-1	0.00
	5/30/00	2	2	0.00
	6/15/00	0	-1	
	7/ 5/00	-3	-2	0.00
	7/24/00	3	2	
20				
	3/14/00	1	1	
	4/ 3/00	-1	1	
	5/15/00	-1	-2	
	5/15/00	0	0	
	6/ 1/00	1	1	0.00
	6/19/00	1	0	0.00
	7/10/00	0	1	0.00
	7/26/00	-1	0	0.00
	8/10/00	1	1	0.00

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	8/30/00	0	0	0.00
	9/18/00	-1	-1	0.00
21				
	5/15/00	2	2	0.00
	5/31/00	0	1	0.00
	6/15/00	0	0	0.00
	7/ 9/00	0	0	0.00
	7/11/00	0	0	
	7/27/00	1	1	0.10
	8/14/00	0	0	0.10
	9/ 5/00	0	0	0.10
22				
	3/13/00	0	0	
	3/29/00	-1	1	
	4/ 4/00	0	0	
	4/18/00	1	1	0.10
	5/ 4/00	0	-1	0.00
	5/22/00	2	2	0.00
	6/12/00	0	0	0.10
	6/29/00	1	0	0.00
	7/13/00	1	0	0.00
	7/30/00	0	0	
	8/21/00	0	0	0.00
	9/ 8/00	0	0	
23				
	9/18/00	0	0	0.00
	10/ 6/00	0	0	0.00
25				
	3/14/00	1	1	
	4/ 3/00	-1	0	
	4/18/00	0	0	0.20

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	5/ 4/00	0	0	0.10
	5/30/00	0	0	0.10
	6/14/00	1	0	
	7/ 9/00	-1	0	0.00
	7/26/00	0	0	0.00
	8/10/00	1	0	0.10
	9/ 5/00	0	0	0.20
26				
	3/27/00	1	1	
	4/ 6/00	-1	0	0.10
	4/24/00	0	0	
	5/15/00	1	0	0.20
	5/31/00	0	1	
	6/ 1/00	0	1	0.10
	6/19/00	0	0	0.10
	7/10/00	0	0	0.10
	7/26/00	-1	-1	0.00
	8/14/00	-1	0	0.30
	9/ 5/00	0	0	0.10
27				
	3/14/00	0	0	
	4/ 3/00	0	1	
	4/20/00	2	2	0.20
	5/15/00	2	3	0.10
	5/31/00	1	2	0.10
	6/26/00	0	0	0.20
	7/12/00	1	1	0.00
	7/30/00	0	0	0.00
	8/21/00	-2	-1	0.00
	9/14/00	0	0	
	10/ 2/00	0	0	0.20

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
28				
	3/29/00	-2	0	
	4/10/00	1	1	
	5/ 1/00	0	0	0.10
	5/16/00	0	0	0.10
	6/ 5/00	2	2	0.20
	6/26/00	-1	-2	0.00
	7/13/00	1	0	0.00
	7/30/00	0	0	0.00
	8/21/00	0	0	0.10
	9/18/00	0	0	-0.10
	10/ 6/00	0	0	0.00

APPENDIX E

STATION-SPECIFIC DATA

Station Specific Data

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
ANQW					
	4/11/00	11	6	-7	-0.09
	4/18/00	16	1	2	0.05
	4/26/00	10	11	0	0.05
	5/ 9/00	18	10	-1	-0.01
	5/23/00	1	18	0	0.06
	6/ 6/00	15	1	10	-0.05
	6/21/00	26	15	-7	0.04
	7/ 6/00	7	26	-4	0.06
	7/19/00	16	7	-1	0.08
	7/30/00	27	16		
	8/16/00	26	27	-1	-0.10
	8/30/00	20	26	0	-0.05
	9/14/00	7	20	4	0.09
DWQI					
	3/16/00	25	26	0	0.03
	3/31/00	5	25	-2	-0.20
	4/11/00	8	5	3	0.12
	4/25/00	9	8	1	-0.13
	4/26/00	14	9	2	0.10
	5/ 9/00	3	14	-1	-0.09
	5/23/00	22	3	1	0.04
	6/ 6/00	2	22	3	0.01
	6/20/00	21	2	-5	0.00
	7/ 6/00	18	21	0	0.01
	7/18/00	1	18	0	-0.03
	7/31/00	22	1	1	0.02
	8/15/00	2	22		
	8/30/00	1	2	0	-0.04
	9/14/00	27	1	4	0.02
	9/21/00	7	27	0	-0.04

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
IDSW					
	3/15/00	18	1	6	-0.07
	3/29/00	9	18	3	-0.11
	4/ 4/00	20	9	2	0.06
	4/19/00	5	20	0	-0.03
	5/17/00	20	19	2	0.06
	6/ 1/00	26	19	-4	-0.10
	6/14/00	7	19	1	0.11
	6/29/00	1	19	1	0.02
	7/12/00	21	19	-1	0.09
	7/27/00	25	19		
	8/ 9/00	16	25	1	-0.13
	8/22/00	22	16	0	0.01
	9/ 8/00	10	22	3	0.00
	9/19/00	20	10	0	-0.01
IHR					
	3/15/00	7	10	-1	-0.01
	3/30/00	22	7	-3	0.00
	4/ 4/00	7	22	2	-0.02
	4/19/00	25	7	1	0.01
	5/ 3/00	16	25	0	0.00
	5/17/00	28	16	-1	0.08
	6/ 1/00	21	28	1	-0.10
	6/14/00	14	21	0	0.00
	6/29/00	5	14	1	-0.11
	7/12/00	21	5	-1	0.01
	7/27/00	20	21	0	0.05
	8/ 9/00	14	20	7	0.14
	8/22/00	28	14	-5	0.07
	9/ 8/00	22	28	-2	-0.06
	9/19/00	23	22	-4	-0.06
LEWI					
	4/11/00	28	16	-1	0.16
	4/26/00	26	28	6	-0.06

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	5/ 9/00	13	26	0	-0.10
	5/24/00	5	13	2	0.03
	6/ 7/00	28	5	0	0.10
	6/20/00	20	28	1	-0.03
	7/ 6/00	10	20	0	-0.09
	7/18/00	13	10	-1	-0.09
	7/30/00	5	13	0	0.05
	8/16/00	21	5	0	0.00
LGNW					
	3/16/00	20	14	5	-0.04
	3/31/00	11	20	0	0.00
	4/ 7/00	14	11	-1	0.04
	4/21/00	7	14	2	0.00
	5/ 5/00	1	7	-2	-0.01
	5/19/00	2	1	1	0.00
	6/ 2/00	27	2	3	0.02
	6/16/00	10	27	6	0.02
	6/30/00	16	10	0	0.09
	7/14/00	27	16	0	-0.04
	7/28/00	26	27	1	-0.03
	8/11/00	20	26	0	0.00
	8/23/00	14	20	0	0.04
	9/ 7/00	26	14	-1	-0.02
LGS					
	4/ 7/00	10	3	0	-0.10
	4/21/00	18	10	1	-0.08
	5/ 5/00	25	18	-1	0.07
	5/19/00	15	25	5	-0.05
	6/ 2/00	20	15		0.04
	6/16/00	18	20	1	-0.01
	6/30/00	13	18	3	-0.02
	7/14/00	28	13	0	-0.12
	7/28/00	21	28	0	-0.05
	8/23/00	10	19	0	-0.03

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	9/ 7/00	3	10	0	-0.04
LGSW					
	4/ 7/00	26	8	-3	-0.04
	4/21/00	3	26	-1	-0.06
	5/ 5/00	5	3	-1	-0.01
	5/19/00	11	5	14	0.03
	6/ 2/00	8	11	2	0.11
	6/16/00	13	8	-1	-0.15
	6/30/00	3	13	2	0.05
	7/14/00	5	3	0	-0.03
	7/28/00	11	5	0	0.03
	8/11/00	8	11	0	0.01
	8/23/00	7	8	0	-0.04
	9/ 7/00	16	7	1	-0.02
LMN					
	4/10/00	27	2	0	0.03
	4/19/00	22	27	2	-0.01
	5/ 4/00	6	22	3	-0.10
	5/18/00	20	6	3	0.07
	6/ 1/00	18	20	3	0.02
	6/15/00	3	18	2	-0.02
	6/29/00	22	3	0	0.00
	7/13/00	2	22	0	0.04
	8/10/00	10	19	0	0.00
	8/22/00	27	10	0	-0.11
	9/ 8/00	8	27	0	0.02
LMNW					
	4/10/00	3	19		
	4/19/00	1	3	1	0.08
	5/ 4/00	2	1	0	0.05
	5/18/00	8	2	4	0.05
	5/31/00	10	8	6	-0.02
	6/15/00	25	10	-1	0.08
	6/29/00	28	25	1	0.02

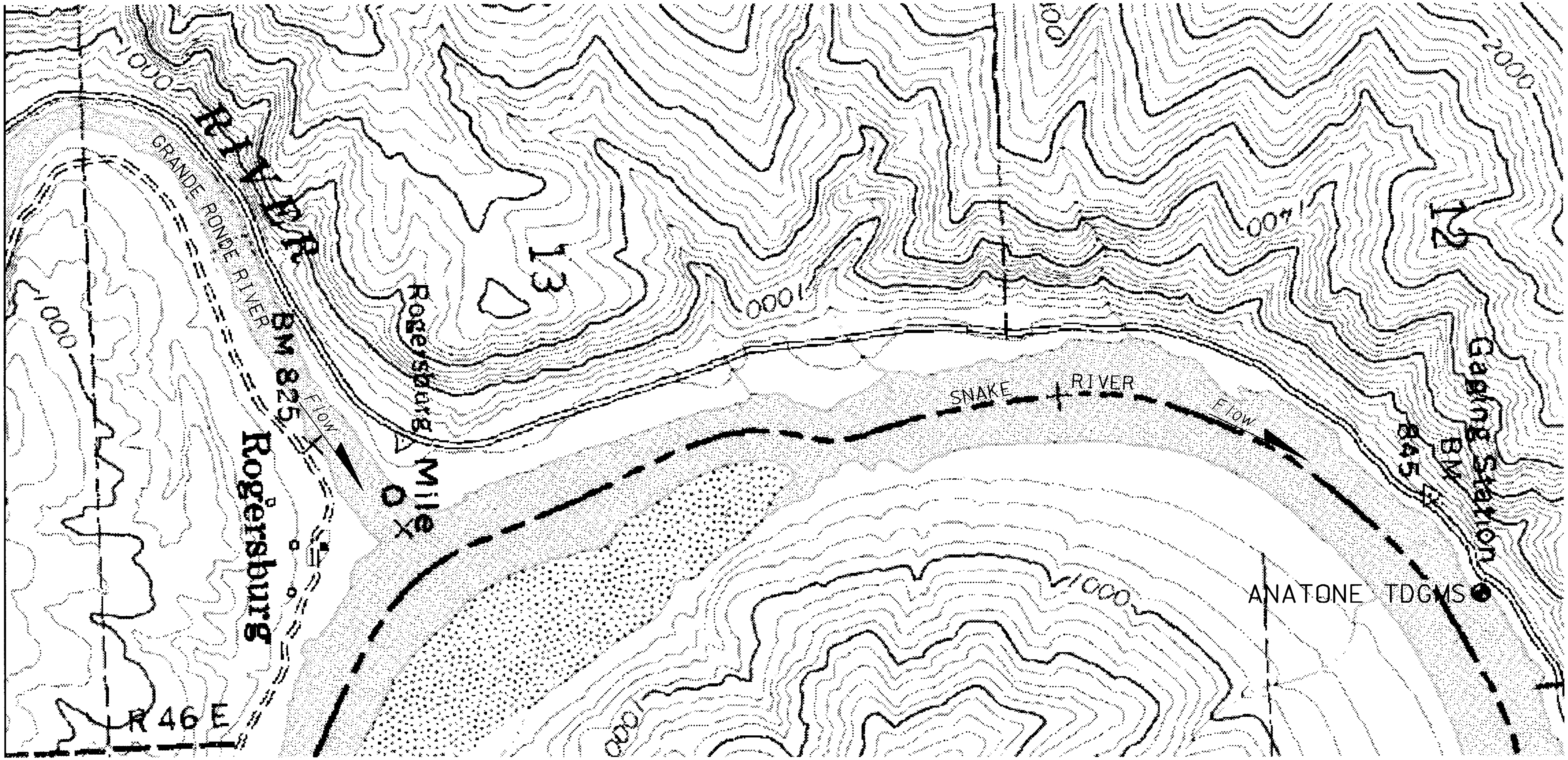
Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	7/13/00	11	28	6	0.00
	7/27/00	8	11	-1	0.06
	8/10/00	7	8	0	0.02
	8/22/00	5	7	1	-0.15
	9/ 8/00	14	23	0	0.08
LWG					
	3/16/00	27	5	0	0.05
	3/31/00	28	27	1	-0.11
	4/ 7/00	9	28	0	-0.10
	4/21/00	27	9	2	0.11
	5/ 5/00	22	27	-4	-0.01
	5/19/00	6	22	3	-0.10
	6/ 2/00	26	6	-1	0.15
	6/16/00	7	26	-3	-0.07
	6/30/00	1	7	0	0.00
	7/14/00	22	1	0	-0.02
	7/28/00	2	22	0	-0.02
	8/11/00	25	2	0	-0.05
	8/23/00	16	25	2	-0.02
MCPW					
	3/14/00	9	25		
	3/28/00	26	9	-1	0.05
	4/ 5/00	25	26	1	-0.02
	5/ 2/00	15	19	3	0.05
	5/16/00	26	15	-4	0.03
	5/31/00	7	26	-2	0.01
	6/13/00	5	7	-2	-0.06
	6/27/00	11	5	-4	0.04
	7/11/00	26	11	-5	0.02
	7/25/00	14	26	-4	0.01
	8/ 9/00	3	14	0	-0.07
	9/ 6/00	2	3	-1	0.02
	9/19/00	28	2	0	0.02
	10/ 6/00	27	28	0	-0.07

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
MCQO					
	3/14/00	22	27	-4	0.00
	3/28/00	14	22	-2	0.00
	4/ 5/00	22	14	-6	-0.02
	5/ 2/00	28	6	-2	0.15
	5/16/00	27	28	0	-0.14
	5/31/00	25	27	-4	0.04
	6/13/00	22	25	-1	-0.03
	6/27/00	27	22	0	-0.17
	7/11/00	8	27	-4	0.03
	7/25/00	7	8	0	-0.01
	8/ 9/00	13	7	1	-0.11
	9/ 6/00	11	19	-3	0.06
	9/19/00	10	11	0	0.06
	10/ 6/00	28	10	-2	0.10
MCQW					
	3/14/00	11	20	0	0.00
	3/28/00	10	11	1	0.02
	4/ 4/00	1	10	-4	-0.08
	5/ 2/00	11	16	1	-0.05
	5/16/00	21	11	-3	0.04
	5/31/00	3	21	1	-0.07
	6/13/00	1	3	-5	0.03
	6/27/00	2	1	1	0.12
	7/11/00	20	2	0	-0.21
	7/25/00	10	20	-3	-0.02
	8/ 9/00	1	10	-1	-0.02
	8/24/00	8	1	0	0.01
	9/ 6/00	21	8	0	-0.01
	9/19/00	2	21	-1	-0.04
	10/ 6/00	23	2	0	0.01
PAQW					
	3/28/00	1	28	0	-0.10
	4/ 4/00	18	1	4	-0.06

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	4/18/00	2	18	0	0.06
	5/ 2/00	8	2	0	0.01
	5/17/00	16	8	-1	0.00
	5/31/00	13	10	-1	-0.10
	6/14/00	16	13	-2	0.12
	6/28/00	15	16	4	-0.06
	7/11/00	25	15		
	7/26/00	18	25	0	-0.12
	9/ 6/00	25	17	0	0.02
PEKI					
	5/ 9/00	7	20	-4	0.07
	5/23/00	16	7	3	0.02
	6/16/00	11	16	3	-0.04
	6/20/00	8	11	-2	0.05
	7/ 6/00	14	8	-1	-0.01
	7/18/00	3	14	1	-0.06
	7/31/00	28	3	0	0.13
	8/15/00	11	28	1	-0.11
	8/30/00	13	11	0	0.08

APPENDIX F

MAPS



N

LEGEND

⊕ STATION LOCATION

600 0 600

SCALE IN FEET

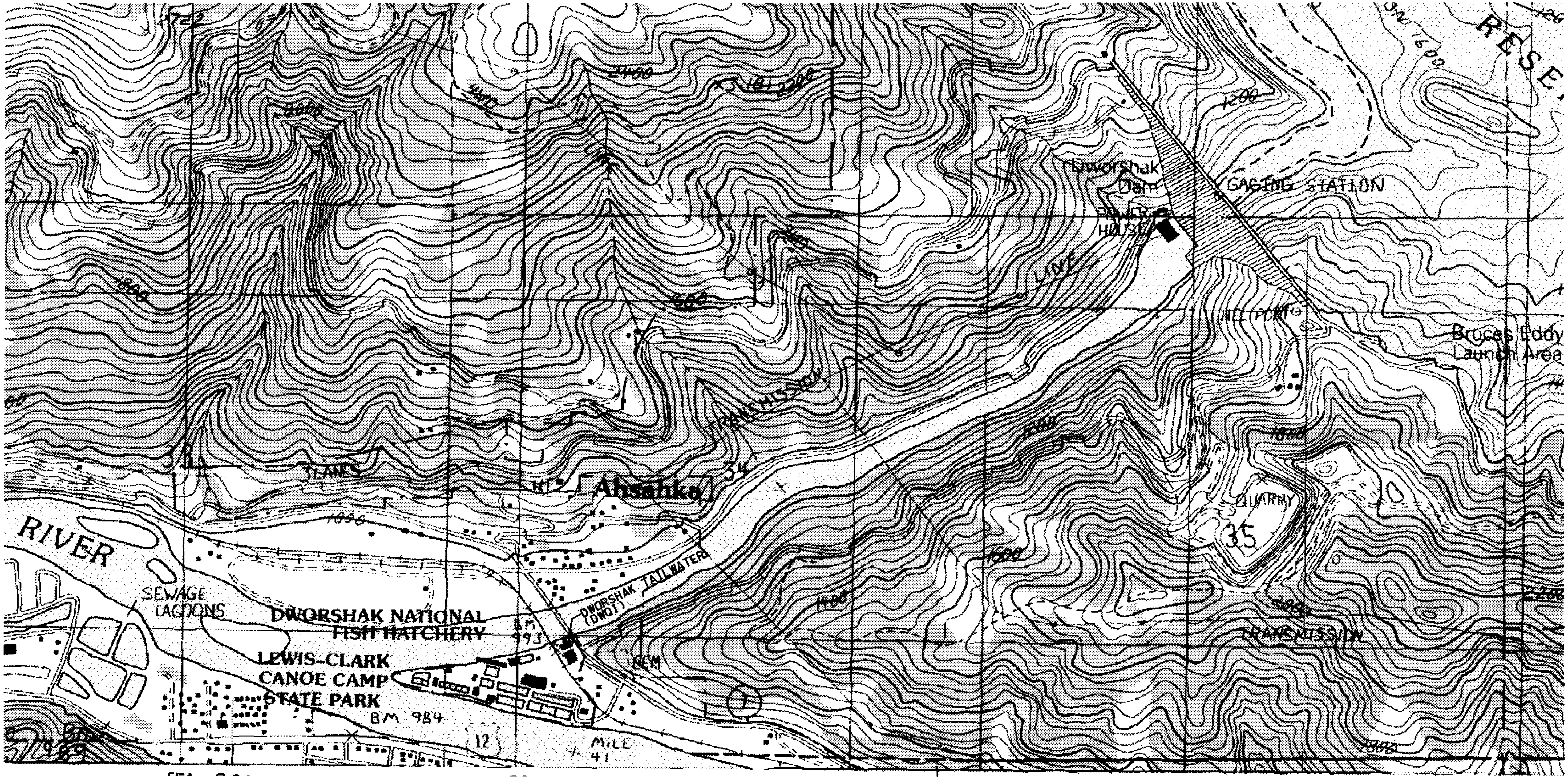
PLATE 1

SNAKE RIVER BASIN

U.S.G.S. GAGING STATION
LOCATION
SNAKE RIVER
NEAR ANATONE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000



N

LEGEND

⊕ STATION LOCATION

• PROBE LOCATION

1000 0 1000

SCALE IN FEET

PLATE 2

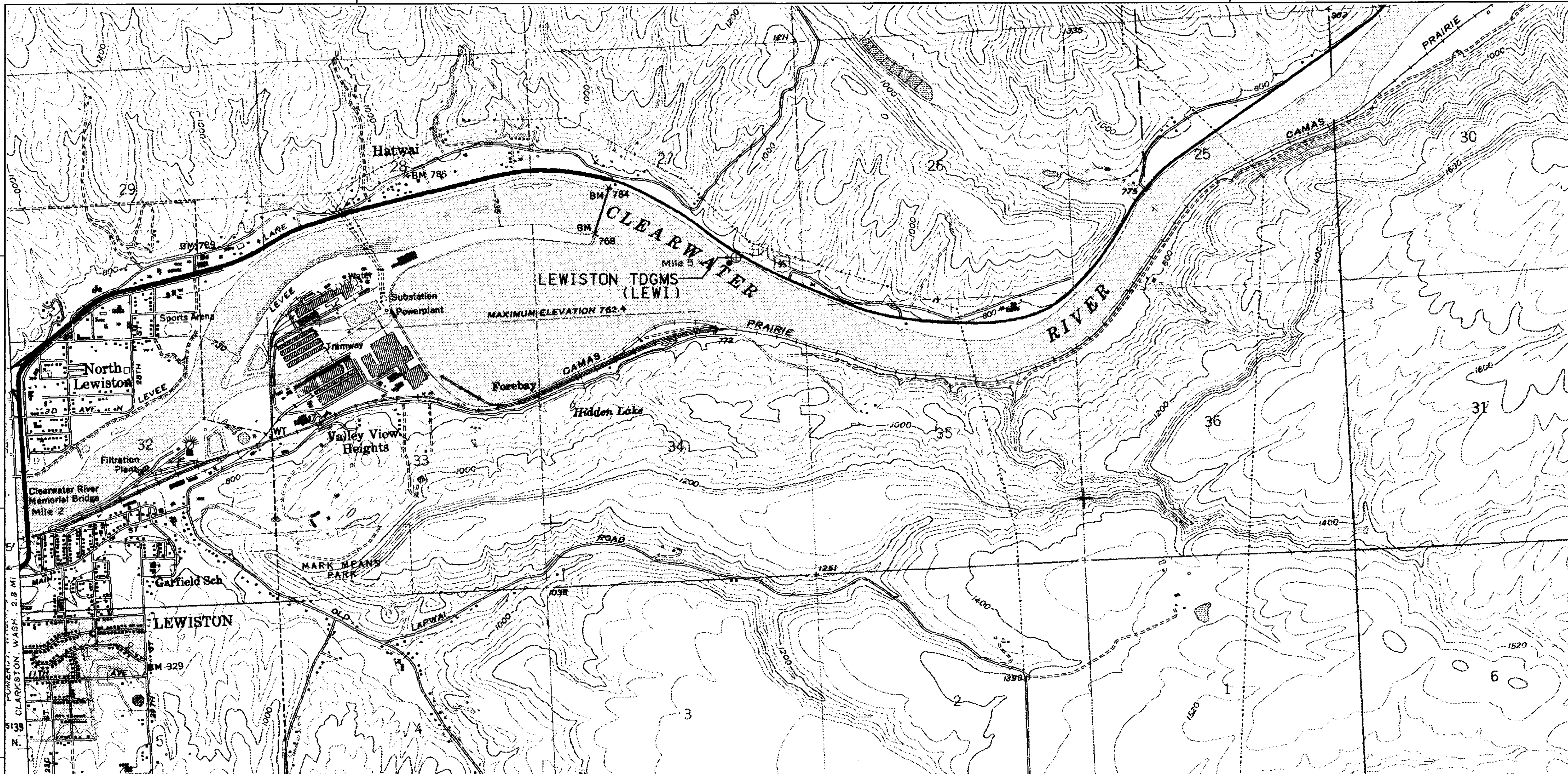
DWORSHAK DAM
CLEARWATER RIVER, IDAHO
VICINITY OF AHSAHKA, IDAHO

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G. SLACK	G. SLACK	OCT. 2000

CORPS OF ENGINEERS SAFETY PAYS U. S. ARMY



NOTE:

1. THE POSITION OF THE LEWISTON TDGMS STATION IS APPROXIMATE THE TIME OF MAPPING. IT IS BELIEVED TO BE WITHIN +/- 500 FEET FROM THE ACTUAL LOCATION.

N

LEGEND

⊕ STATION LOCATION

• PROBE LOCATION

2000 0 2000

SCALE IN FEET

PLATE 3

CLEARWATER RIVER, IDAHO
VICINITY OF LEWISTON, IDAHO
LEWISTON TDGMS STATION

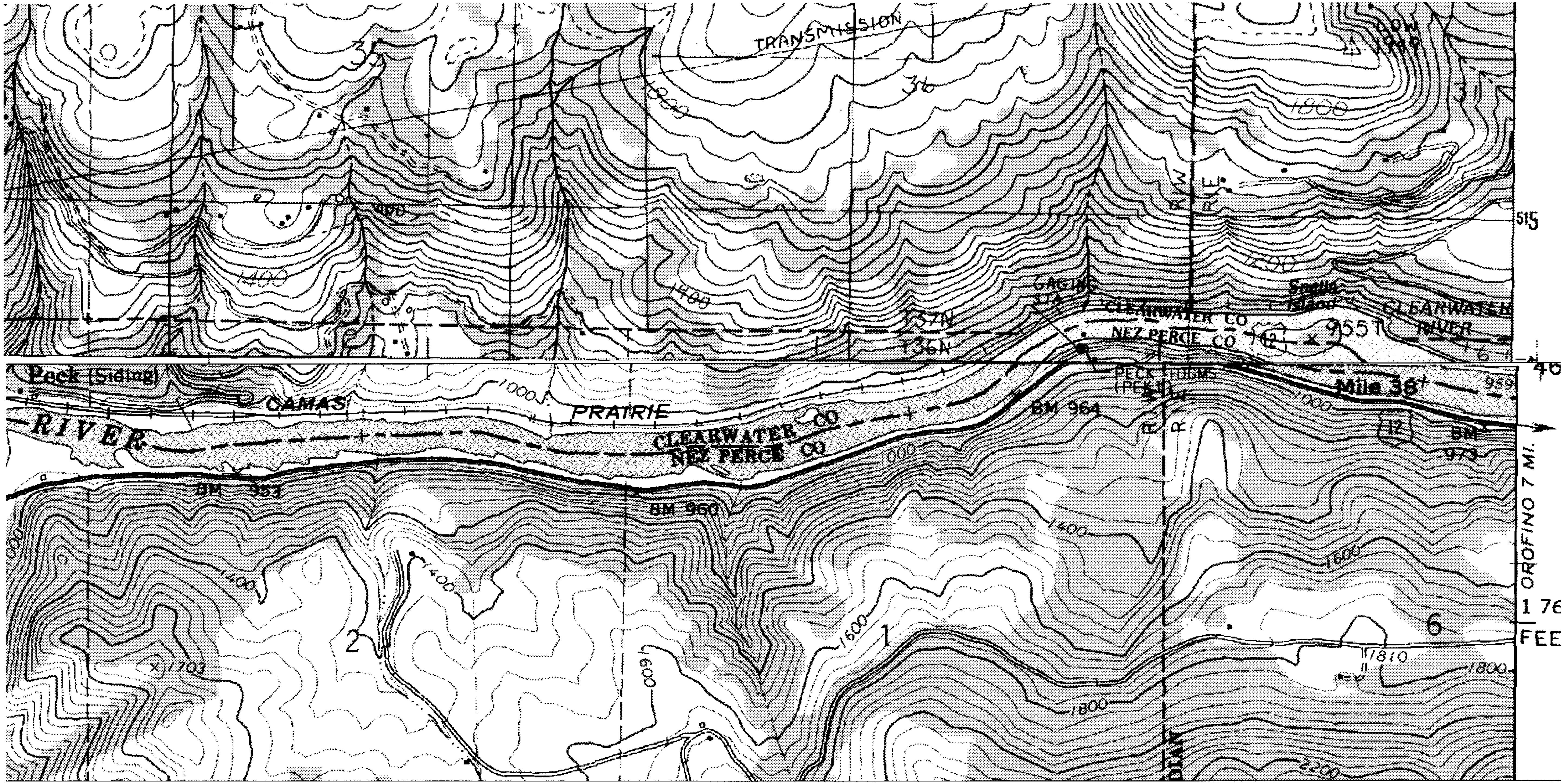
TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT

WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G.SLACK	G. SLACK	OCT 2000

VALUE ENGINEERING PAYS



N

LEGEND

⊕ STATION LOCATION
• PROBE LOCATION

1000 0 1000
SCALE IN FEET

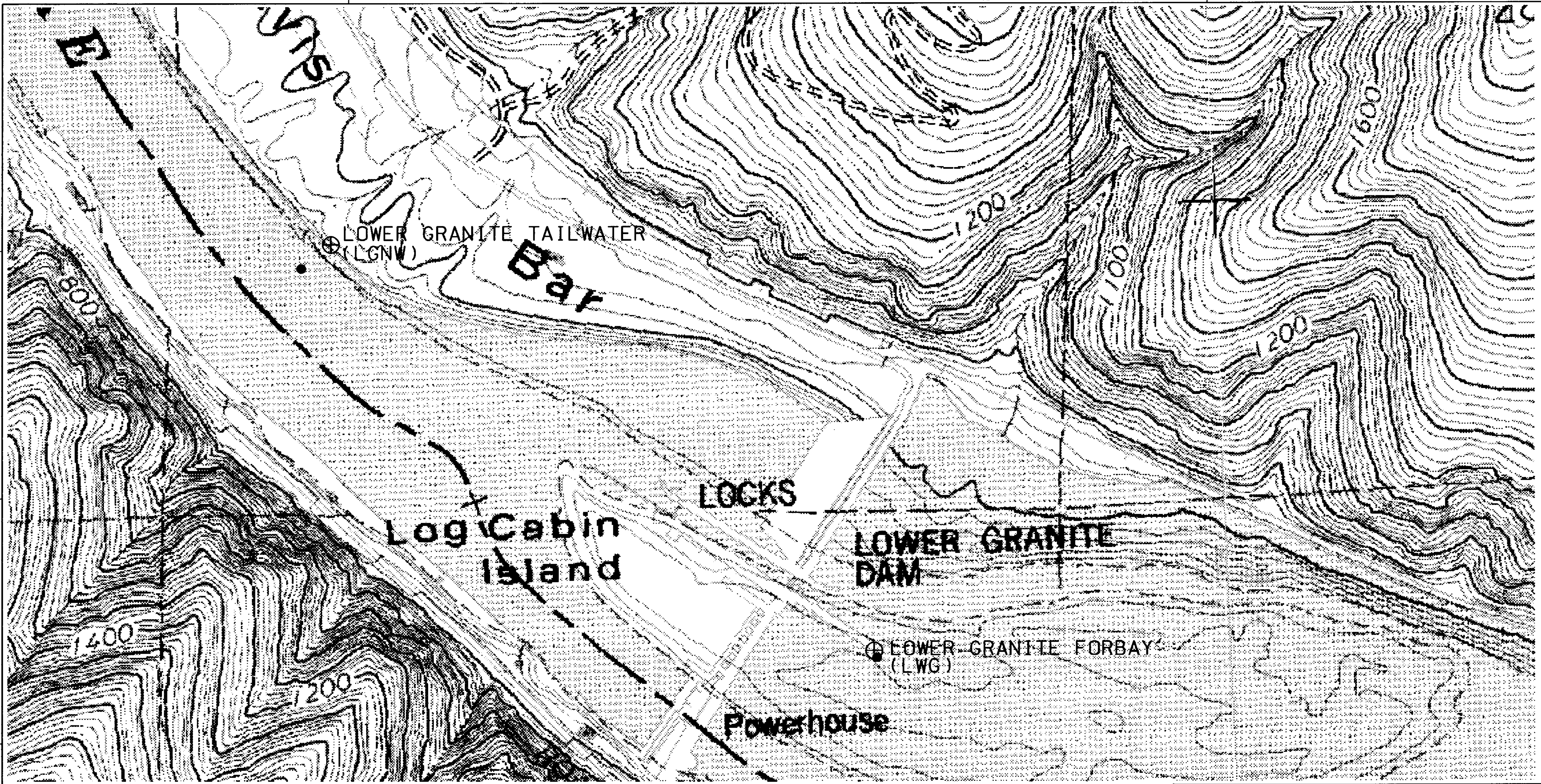
PLATE 4

CLEARWATER RIVER, IDAHO
VICINITY OF PECK, IDAHO
PECK TDGMS STATION

TOTAL DISSOLVED GAS MONITORING
SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G. SLACK	G. SLACK	OCT. 2000



N

LEGEND

- ⊕ STATION LOCATION
- ● PROBE LOCATION

600 0 600
SCALE IN FEET

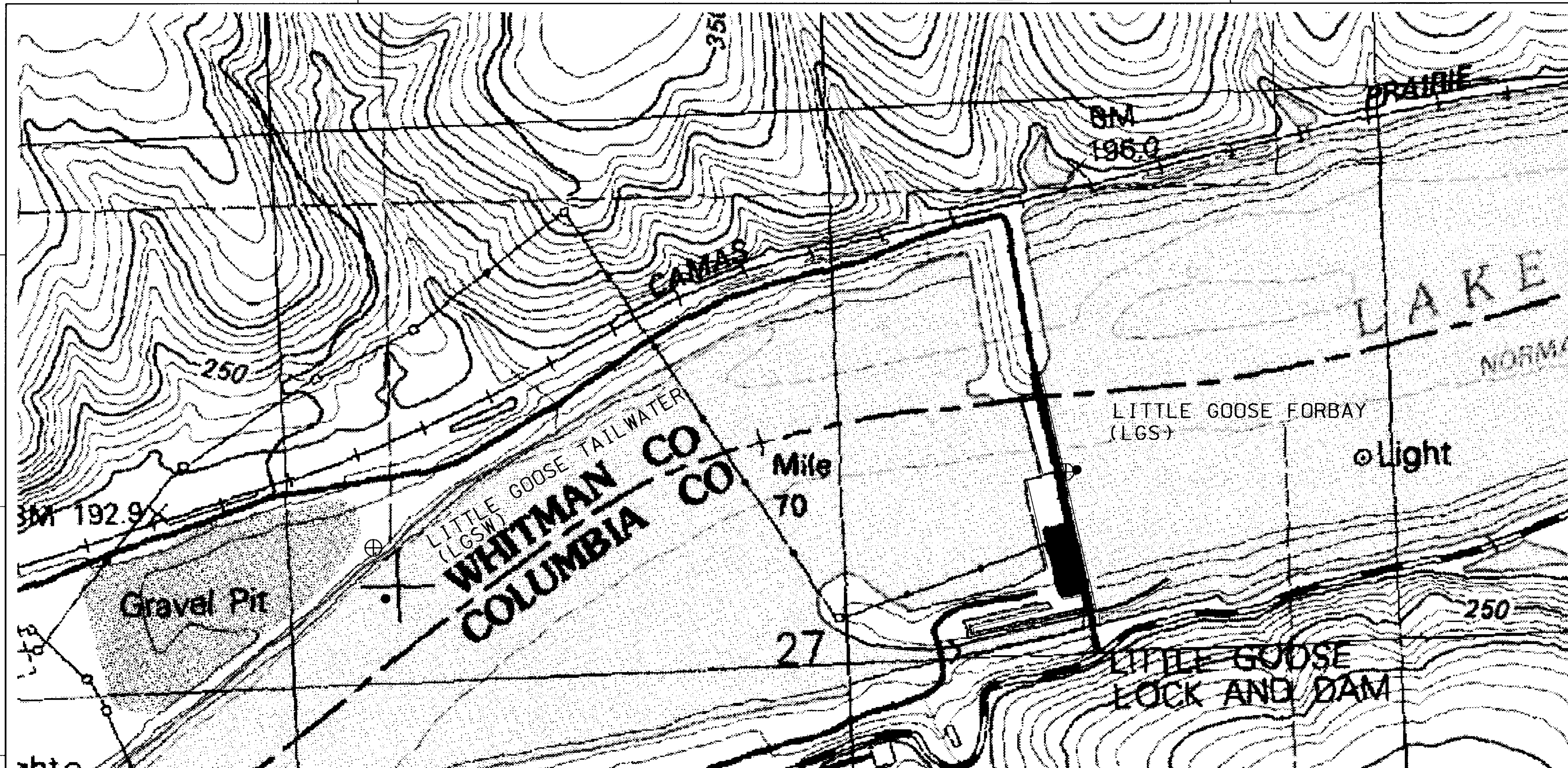
PLATE 5

LOWER GRANITE LOCK AND DAM
SNAKE RIVER, WASHINGTON

TOTAL DISSOLVED GAS
MONITORING SYSTEM
STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000



N

LEGEND
- ⊕ STATION LOCATION
- ● PROBE LOCATION

600 0 600
SCALE IN FEET

PLATE 6

LITTLE GOOSE LOCK AND DAM
SNAKE RIVER, WASHINGTON

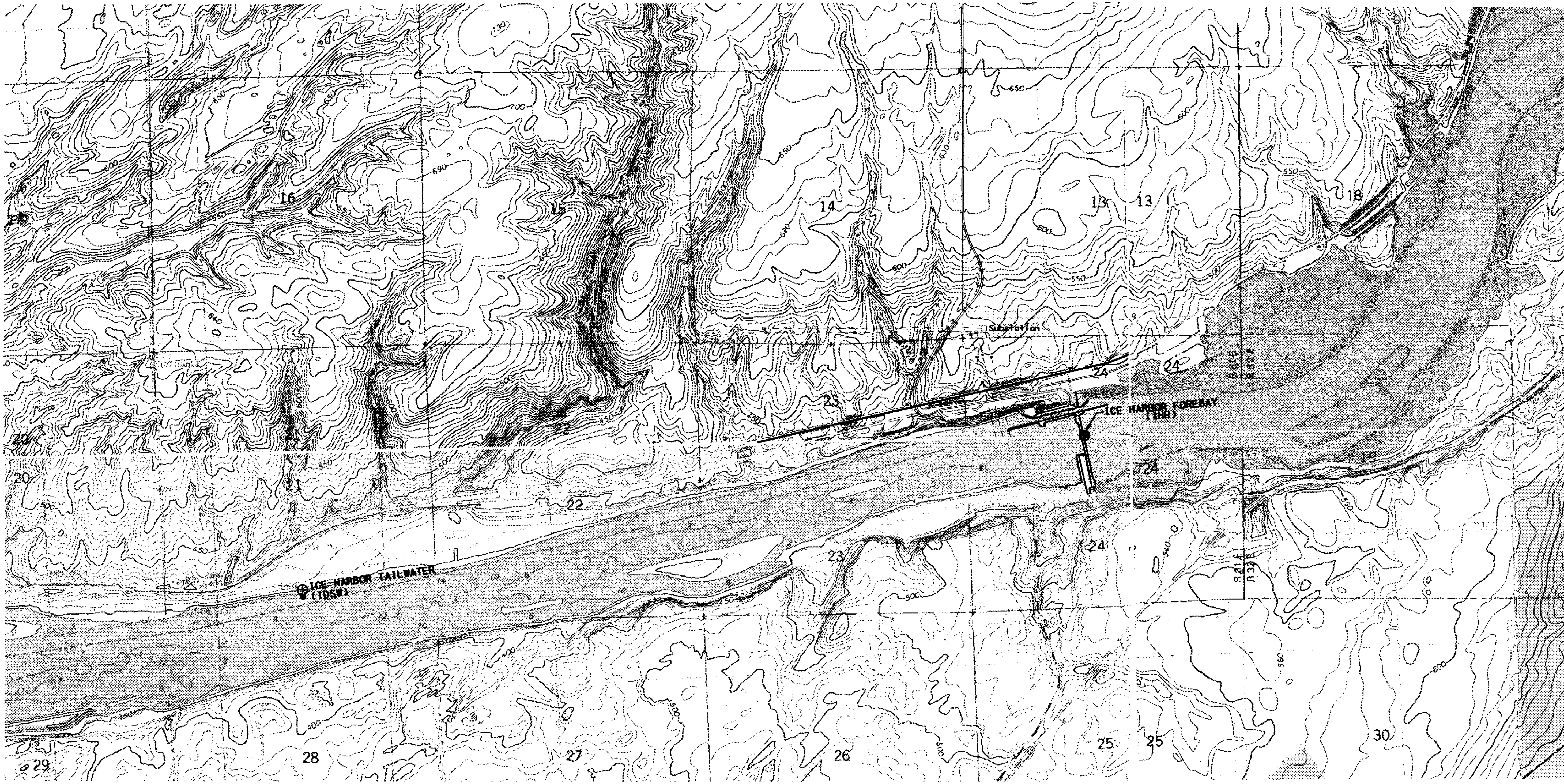
TOTAL DISSOLVED GAS
MONITORING SYSTEM
STATION LOCATIONS

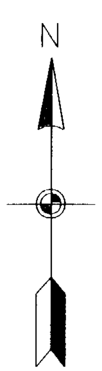
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000

MAP 4

CORPS OF ENGINEERS | SAFETY PAYS | U. S. ARMY





LEGEND

⊕ STATION LOCATION

• PROBE LOCATION

2000 0 2000

SCALE IN FEET

PLATE 7

ICE HARBOR LOCK AND DAM
SNAKE RIVER, WASHINGTON

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

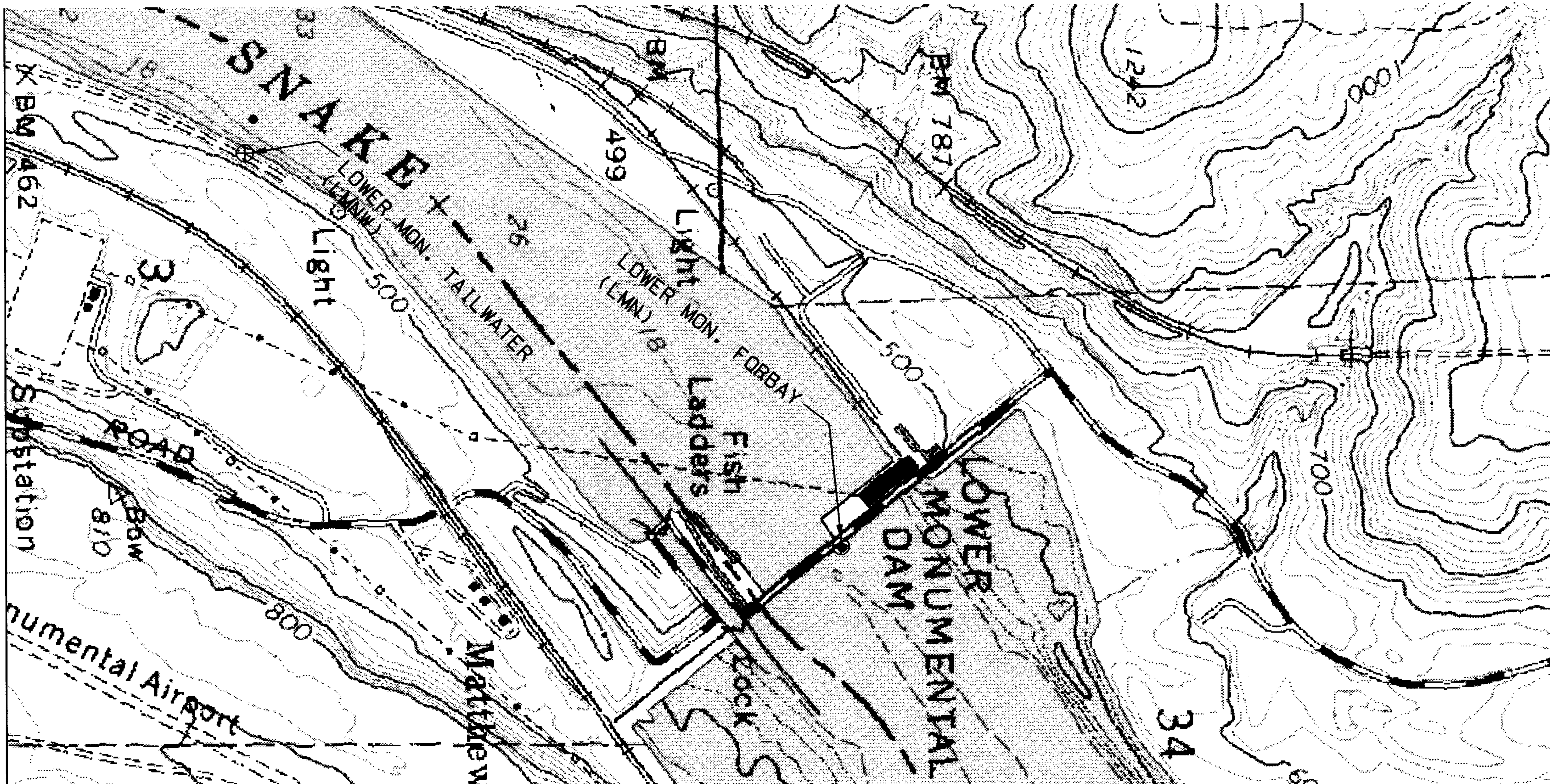
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G.SLACK	G. SLACK	OCT 2000

VALUE ENGINEERING PAYS

MAP 2

CORPS OF ENGINEERS SAFETY PAYS U. S. ARMY



N

LEGEND

⊕ STATION LOCATION

● PROBE LOCATION

600 0 600

SCALE IN FEET

PLATE 8

LOWER MONUMENTAL LOCK AND DAM
SNAKE RIVER, WASHINGTON

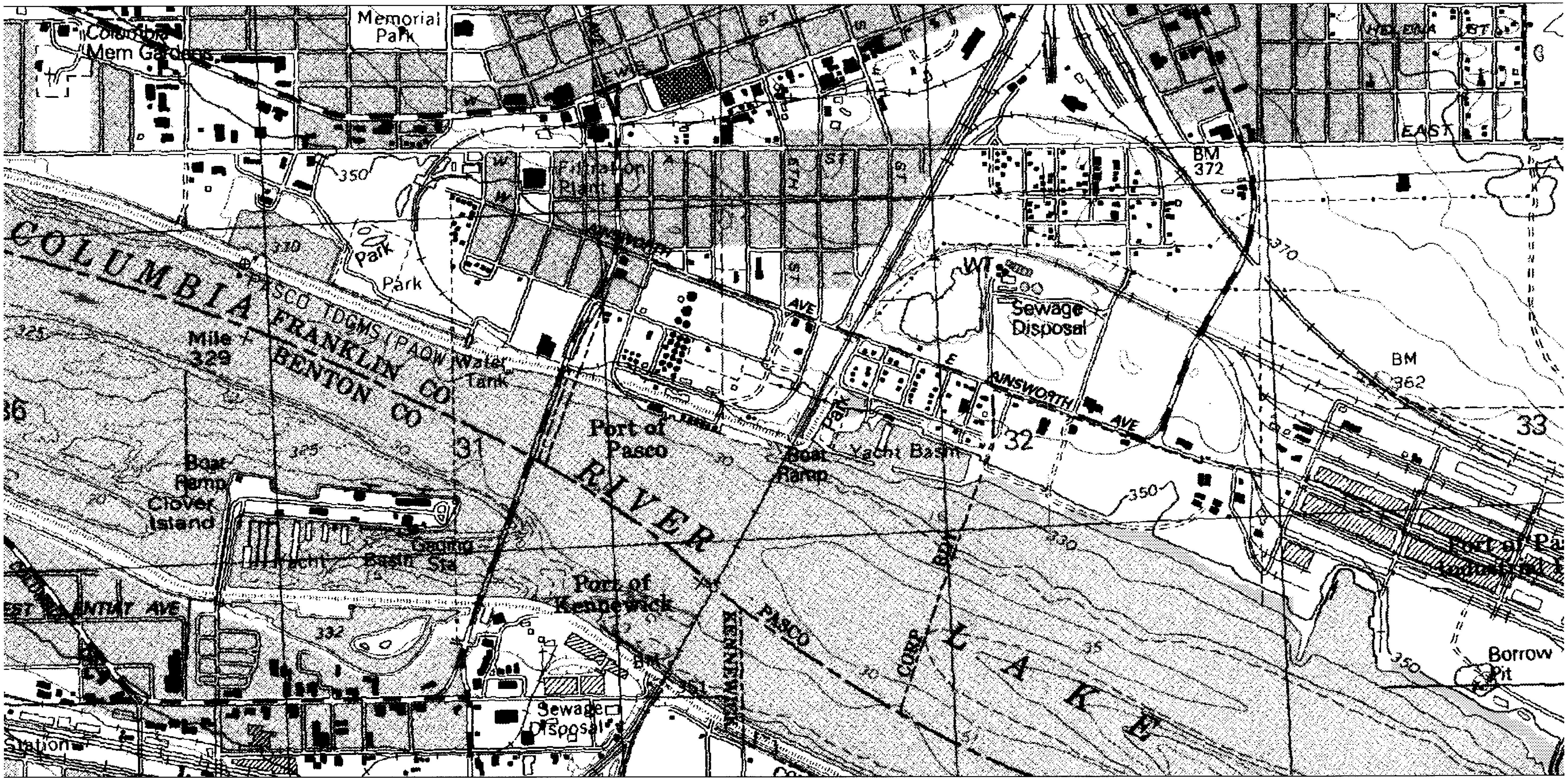
TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000

VALUE ENGINEERING PAYS

MAP 3



N

LEGEND

⊕ STATION LOCATION

• PROBE LOCATION

1000 0 1000

SCALE IN FEET

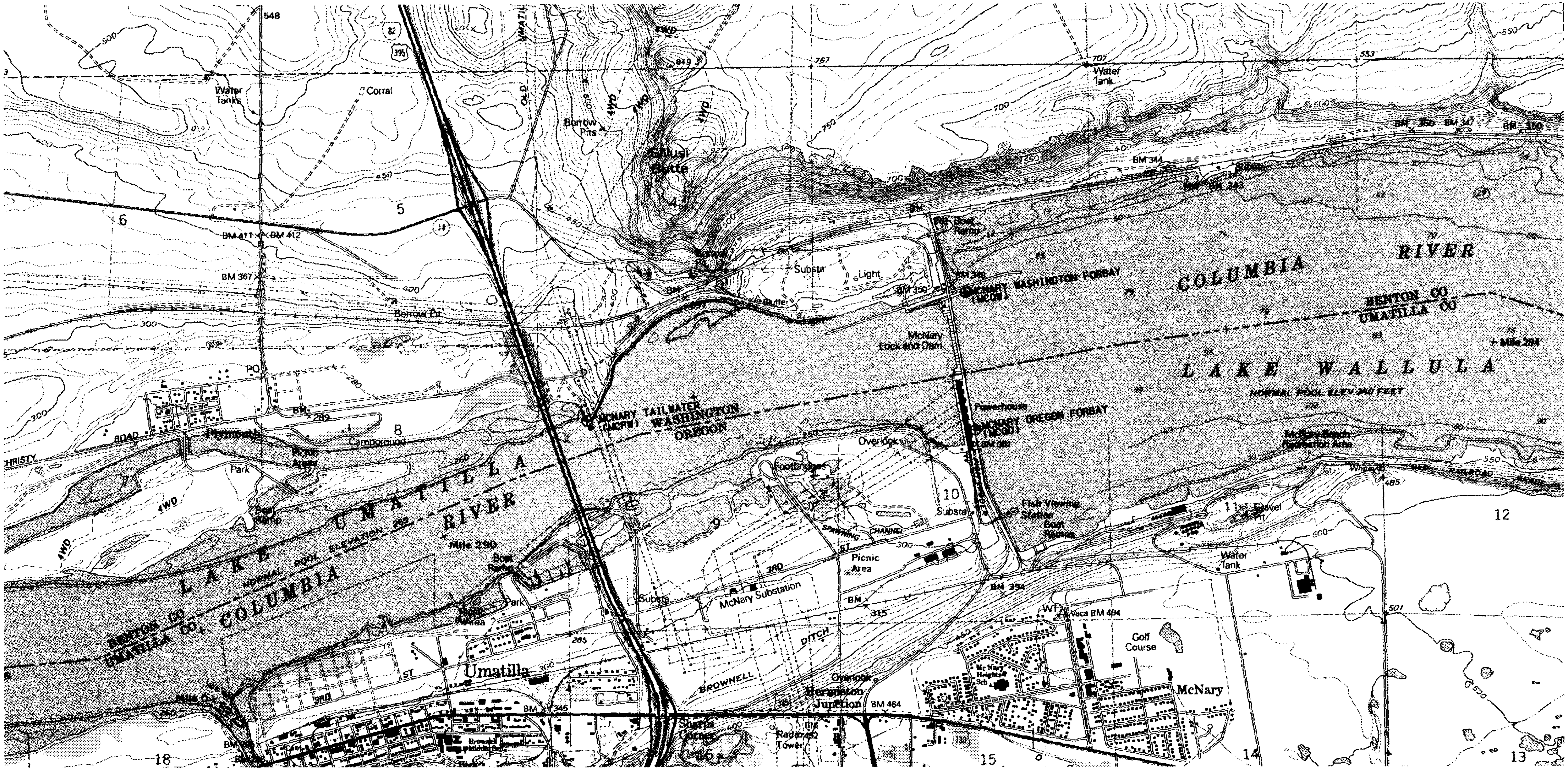
PLATE 9

COLUMBIA RIVER, WASHINGTON
VICINITY OF PASCO, WASHINGTON

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G. SLACK	G. SLACK	OCT. 2000



N

LEGEND
⊕ STATION LOCATION
• PROBE LOCATION

2000 0 2000
SCALE IN FEET

PLATE 10

MCNARY LOCK AND DAM
COLUMBIA RIVER, WASHINGTON AND OREGON

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G.SLACK	G. SLACK	OCT 2000